Chapter 9 Modeling and Assumptions

A suite of simulation models were used to analyze effects of proposed Central Valley Project (CVP) and State Water Project (SWP) operations on steelhead, coho salmon, delta smelt, green sturgeon, and winter-run and spring-run Chinook salmon. This chapter presents the modeling tools, study assumptions, sensitivity and uncertainty evaluations, and limitations. In addition, key simulated summary results are included under a range of assumed conditions.

The following simulation models were used to quantify effects:

- Hydrologic- (CalSim-II and CalLite)
- Delta Hydrodynamics - (DSM2)
- Temperature - (Reclamation Temperature, Sacramento Rivers Water Quality Management [SRWQM], and Feather River)
- Salmon Mortality, Population, and Life Cycle - (Reclamation Mortality, SALMOD, and Interactive Object-Oriented Salmon Simulation [IOS])
- Climate Change and Sea Level Rise - (Sensitivity Analysis)
- Sensitivity and Uncertainty - (CalSim-II)

Modeled future assumptions changes in operations expected to affect the CVP and SWP are:

- Limited Environmental Water Account Program
- Lower Yuba River Accord
- Freeport Regional Water Project
- Level of development (full contract/Table A demand in future)
- Sacramento River Water Reliability Project
- American River Flow Management
- New Melones Draft Transitional Operation Plan
- The California Aqueduct (CA) and Delta-Mendota Canal (DMC) Intertie
- South Delta Improvement Project Stage 1 (permanent gates)
- Red Bluff Diversion Dam

The modeling is comprised of studies that represent the following range of conditions:

- Present
- Near Future
- Future
- Future with climate change and sea level rise

The Operations Criteria and Plan (OCAP) Biological Assessment (BA) modeling is defined as the quantitative simulation of the CVP and SWP (within the extent possible, using the best available tools) to identify if a current action or proposed action may affect listed or proposed species, or designated or proposed critical habitat which is protected by the Endangered Species Act (ESA). The following general metrics were identified to prepare this biological assessment:

- River flows
- Reservoir storage
- Sacramento-San Joaquin Delta exports, hydrodynamics, and salinity
- River temperature
- Salmon life cycle and mortality

The objective was to provide the above identified metrics resulting from the CVP and SWP system operations under various hydrologic and assumed conditions (see Studies and Assumptions). Specific metrics used in the evaluation of the biological effects analysis are identified and discussed in Chapter 11: Upstream Effects and Chapter 13: Delta Effects.

Modeling Methods

Model simulations describe water surface storage, conveyance, water quality, temperature, and salmon lifecycle and mortality for the Central Valley and Sacramento-San Joaquin Delta. The suite of simulation models developed and/or applied by Reclamation and DWR include:

- Statewide planning model of water supply, stream flow, and Delta export capability (CalSim-II and CalLite)
- Sacramento-San Joaquin Delta hydrodynamics and particle tracking (DSM2)
- River temperature (Reclamation Temperature, SRWQM, and Feather River Model)
- Salmon mortality (Reclamation Mortality, SALMOD, and IOS)

Specific model methodologies for CalSim-II, DSM2, temperature models, salmon models, climate change and sea level rise, and sensitivity and uncertainty are briefly described in the sections below.

The modeling process for this BA uses a tiered approach where models function independently and are not dynamically linked. After CalSim-II modeling results were complete, they were used as input to the DSM2 model to find hydrodynamic conditions in the Delta. CalSim-II results were also used in temperature models that provide estimates of mean monthly temperatures at a variety of locations and mean daily temperature at select locations along CVP- and SWP-influenced rivers. Modeled temperatures were then compared to thermal criteria for specific life stages in the months when they would be present in the given river as the primary means of assessing potential effects of proposed CVP and SWP operations. These results were used to assess potential effects for proposed CVP and SWP export operations. This process is used to maintain consistency amongst the model results. The models and data flow are graphically shown in Figure 9-1. A list of temporal model characteristics is presented in Table 9-1.

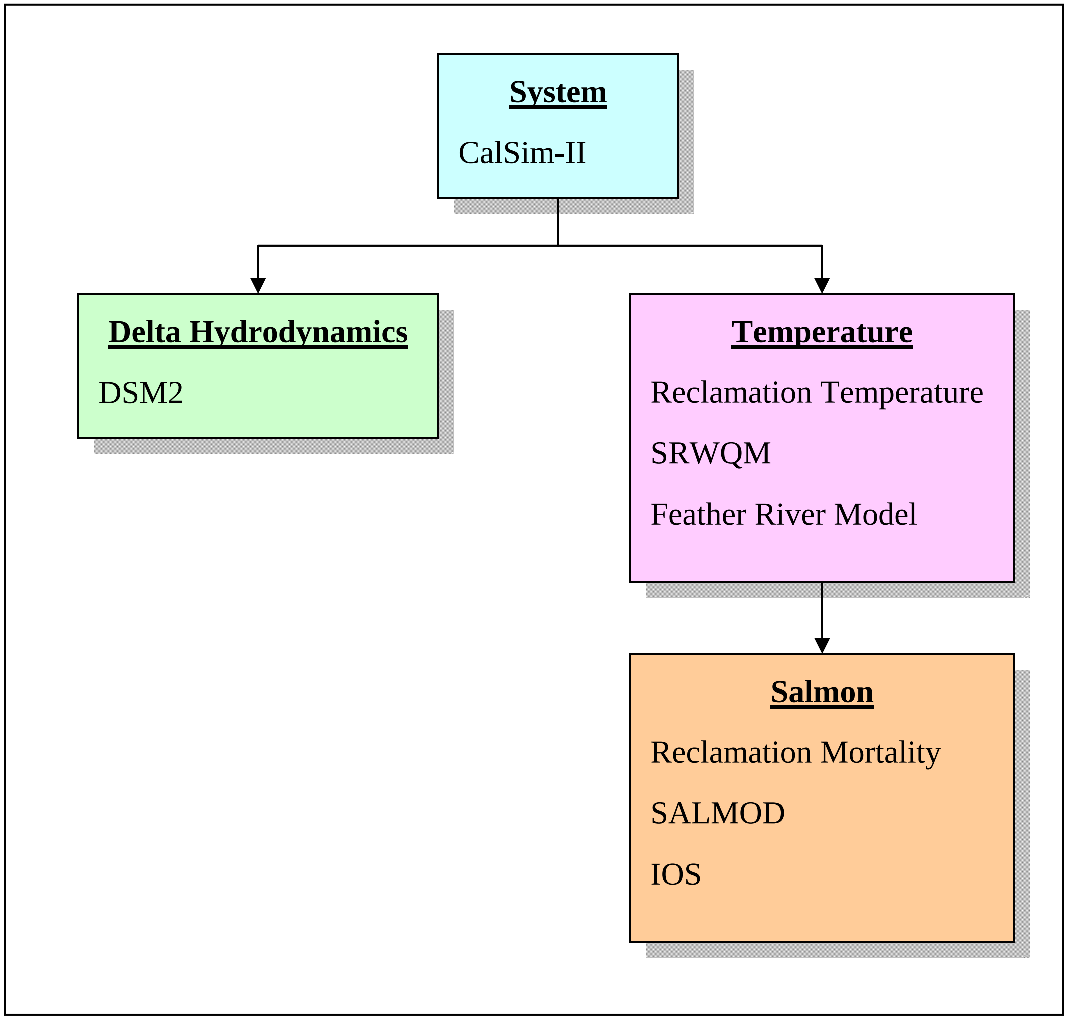

Figure 9-1 OCAP BA Model Information Flow

Table 9-1 Temporal and Simulation Characteristics

Model	Model Time Step	Simulation Period (Water Year)
CalSim-II	Monthly	1922-2003
DSM2	15 minute	1976-1991
Reclamation Temperature	Monthly	1922-2003
SRWQM	6 hour	1922-2003
Feather River Model	1 hour	1922-1994
Reclamation Mortality	Daily	1922-2003
SALMOD	Weekly	1922-2003
IOS	Daily	1923-2002

The simulation results of the OCAP BA are designed for a comparative evaluation because the CalSim-II model uses generalized rules to operate the CVP and SWP systems and the results are a gross estimate that may not reflect how actual operations would occur. Generalizations are also made for various programs based on adaptive management that are too dynamic in nature to codify or capture the wide spectrum of factors used in actual decision making. Results should only be used as a comparative evaluation to reflect how changes in facilities and operations may affect the CVP-SWP system. Biological effects assessing future conditions in the OCAP BA using simulated results were based on comparative evaluations. While models can provide useful insight to complex systems or overcome the deficiencies of incomplete observed data, they are a simplification of the true system or natural processes and yield results with limitations (see Modeling Limitations).

The model appendices (Appendices D, F, H, J, L, N, P, and R) document efforts to demonstrate tangible measures of OCAP BA modeling adequacy, credibility, data quality, model testing, sensitivity, and uncertainty. The results presented (Appendices E, G, I, K, M, O, Q, S, and T) are the product of the best science available at the time this document was prepared. For example, CalSim-II is the SWP-CVP simulation model developed and used by the DWR and the Reclamation. CalSim-II represents the best available planning model for the CVP-SWP system as quoted in the April 9, 2004, Draft Response Plan from the CALFED Science Program Peer Review of CalSim-II:

> *"As the official model of those projects, CalSim-II is the default system model for any inter-regional or statewide analysis of water in the Central Valley…California needs a large-scale relatively versatile inter-regional operations planning model and CalSim-II serves that purpose reasonably well."*

Hydrologic Modeling Methods

The objective of the hydrologic models is to simulate the CVP and SWP project operations with a set of historical hydrology (water-years 1922 to 2003) with existing and assumed future conditions. These results provided the inputs to hydrodynamic and temperature models that assist in the fisheries effects evaluations of alternative CVP/SWP operations. Both the CalSim-II and CalLite models produce monthly results. These results are used to examine the seasonal and water year type (Wet, Above Normal, Below Normal, Dry, and Critical) trends in a comparative manner (as described previously).

CalSim-II

The CalSim model is a water resources simulation planning tool developed jointly by DWR and Reclamation. The CalSim-II model is applied to the SWP, the CVP, and the Sacramento and San Joaquin Delta (Figure 9-2). The model is designed to evaluate the performance of the CVP and SWP systems for: existing or future levels of land development, potential future facilities, current or alternative operational policies and regulatory environments. Key model output includes reservoir storage, instream river flow, water delivery, Delta exports and conditions, biological indicators, and operational and regulatory metrics.

CalSim-II simulates 82 years of hydrology for the region spanning from water year 1922 to water year 2003. The hydrology data is composed of assumed water demands, stream accretions and depletions, stream-groundwater interaction, rim basin inflows, irrigation efficiency, return flows, and non-recoverable losses. The model employs an optimization algorithm to find routing solutions on monthly time step. The movement of water in the system is governed by an internal weighting structure to ensure regulatory and operational priorities. The Sacramento and San Joaquin Delta (Delta) is also represented by DWR’s Artificial Neural Network (ANN), which simulates flow and salinity relationships. Delta flow and electrical conductivity is also reported at key regulatory locations. Details of the level of land development (demands) and hydrology and ANN are discussed in Appendix D.

CalSim-II water deliveries are simulated for water contractors based on a method that estimates the actual forecast allocation process. The North of Delta (NOD) and South of Delta (SOD) deliveries for both the CVP and SWP contractors are determined using a set of rules for governing the allocation of water. CalSim-II uses a water supply and water demand relationship to find delivery quantities given available water, operational constraints and desired reservoir carryover storage volumes. Additional details of the delivery allocation process are available in Appendix D.

CalSim-II simulates a suite of environments to represent the CVP and SWP systems. The regulatory environments consist of the SWRCD D-1485, and the D-1641 (also referred to as the 1995 Water Quality Control Plan “WQCP”). These two environments are necessary for the determination of the CVPIA (b)(2) regulatory environment which implements fish protection actions and is next in the sequence. Following the (b)(2) environment is the conveyance step (formerly known as the Joint Point of Diversion (JPOD)) where water is exported or “wheeled” at the Delta pumping facilities. Next is the Transfers environment. This environment is deactivated and no transfers are dynamically simulated for these studies. However, a post-processed transfer analysis is evaluated. The final regulatory environment is the Environmental Water Account (EWA) or the Limited EWA (the Lower Yuba River Accord transfers are dynamically simulated in the EWA regulatory environment). The following discussion details the CVPIA (b)(2) and the EWA specific for the OCAP BA.

Figure 9-2 General spatial representation of the CalSim-II network

CVPIA 3406 (b)(2) and Environmental Water Account Modeling

CalSim-II dynamically models Central Valley Project Improvement Act (CVPIA) 3406(b)(2) and the Environmental Water Account (EWA). CVPIA 3406(b)(2) accounting procedures in CalSim-II are based on system conditions under operations associated with SWRCB D-1485 and D-1641 regulatory requirements (DWR 2002). Similarly, the operating guidelines for selecting actions and allocating assets under the EWA are based on system conditions under operations associated with a Regulatory Baseline as defined by the CALFED Record of Decision which includes SWRCB D-1641 and CVPIA 3406 (b)(2), among other elements. Given the task of simulating dynamic EWA operations, and the reality of interdependent operational baselines embedded in EWA's Regulatory Baseline, a modeling analysis was developed to dynamically integrate five operational baselines for each water year of the hydrologic sequence.

CVPIA (b)(2)

Consistent with CVPIA, Reclamation manages the CVP to "dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary; and to help to meet such obligations as may be legally imposed upon the Central Valley Project under State or Federal law following the date of enactment of this title, including but not limited to additional obligations under the Federal Endangered Species Act."

The water allotted under the authorization of CVPIA (b)(2) is dedicated and managed in a manner consistent with processes outlined in Chapter 2 and are generally managed to augment river flows and to limit pumping in the Delta to supplement the requirements of D-1641 and to protect fish species.

To simulate the 3406 (b)(2) accounting, the model uses metrics calculated in the (b)(2) simulation. The metrics measure the flow increases and export decreases from D-1485 to D-1641 WQCP Costs, and from D-1485 to (b)(2), total (b)(2) costs. The following assumptions were used to model the May 2003 3406 (b)(2) Department of the Interior decision.

1. **Allocation of (b)(2) water** is 800,000 acre-feet per year (af/yr), 700,000 af/yr in 40-30-30 Dry Years, and 600,000 af/yr in 40-30-30 Critical years
2. **Upstream flow metrics** are calculated at Clear Creek, Keswick, Nimbus, and Goodwin Reservoirs where (b)(2) water can be used to increase flow for fishery purposes. For OCAP BA modeling purposes, CVPIA (b)(2) accounting of Goodwin releases and volumes are independently determined based on Stanislaus River water availablity and New Melones water allocation estimates. The assumptions used in CalSim-II for taking an upstream action at one of the previously mentioned reservoirs are:
    - **October-January**
        - Clear Creek Releases: Action is on if Trinity Beginning of Month Storage >600,000 af.
        - Keswick Releases: Action is on if Shasta Beginning-of-Month Storage > 1,900,000 af.

    - Nimbus Releases: Action is on if Folsom Beginning-of-Month Storage > 300,000 af.
    - For all releases, if the 200,000-af target is projected to be violated the model will try to reduce the magnitude of the actions in December and/or January.
- **February-September**
    - Clear Creek Releases: Action is on if Trinity Beginning of Month Storage >600,000 af.
    - Keswick Releases: Action is on if Shasta Beginning-of-Month Storage > 1,900,000 af and if remaining (b)(2) account > projected coming WQCP costs.
    - Nimbus Releases: Action is on if Folsom Beginning-of-Month Storage > 300,000 af and if remaining (b)(2) account > projected coming WQCP costs.

3. **The export metric** is the change in total CVP pumping (Jones + CVP Banks) from the base case (D1485). Assumptions used in CalSim-II for taking a delta action are:
    - **Winter Actions** (December through February) and Pre-Vernalis Adaptive Management Plan (VAMP) (April Shoulder) actions are off.
    - **VAMP Actions**: Always taken and done at a 2:1 ratio (Vernalis flow to CVP pumping ratio) if non-VAMP Vernalis flows are greater than 8,600 cubic feet per second (cfs).
    - **May Shoulder**: Action turned on if the remaining (b)(2) is greater than or equal to the discounted remaining WQCP cost + anticipated Clear Creek cost (25,000 af). DISCOUNT = If the annual WQCP cost > 500,000 af, the difference is subtracted from the remaining WQCP cost.
    - **June Ramping**: Action turned on if the remaining (b)(2) is greater than or equal to the discounted remaining WQCP cost + anticipated Clear Creek cost (20,000 af).
    - **Both May Shoulder and June Ramping** are further restricted to stay within the remaining (b)(2)account – remaining WQCP costs.

Environmental Water Account

The three management agencies (FWS, NMFS, and DFG) and the two project agencies (Reclamation and DWR) share responsibility for implementing and managing the Environmental Water Account (EWA) as described in Chapter 2. The objective of simulating EWA for OCAP BA modeling is to represent the functionality of the program in two ways: as it has been implemented by EWAT during WY2001-2007, referred to as Full EWA and as it is foreseen to be implemented in a limited capacity in coming years, referred to as Limited EWA. The EWA representation that CalSim-II simulates is not a prescription for operations; it is only a representation of the following EWA operating functions:

- Implementing actions at SWP and CVP Delta export facilities
- Assessing debt caused by these actions
- Year-to-year carryover debt was represented for Full EWA, but not for Limited EWA
- Acquiring assets for managing debt

- Storing assets in San Luis, and transferring (or losing) stored assets to the projects as a result of projects' operations to fill San Luis during winter months
- Spending assets to compensate for debt south of the Delta (SOD)
- Tracking and mitigating the effects of debt north of the Delta (NOD) and NOD backed-up water
- Spilling carryover debt to the SWP at San Luis Reservoir was represented for Full EWA, but not for Limited EWA
- Conveyance of assets from NOD to SOD
- Accounting system re-operation effects resulting from EWA operations

For the OCAP BA modeling, action definitions reflect monthly to seasonal aggregate actions implemented by EWAT from WY2001-2007 and in the immediately foreseeable future.

Full EWA

The following actions are simulated in the OCAP BA modeling for Full EWA fishery purposes:

- **Winter-period Export Reduction (December–February):**

  Definition: "Asset spending goal" where a constraint is imposed on total Delta exports that equal 50,000 af less per month relative to the amount of export under the Regulatory Baseline. This is modeled as a monthly action and conceptually represents EWAT implementation of multiple several-day actions during the month.

  Trigger: All years for December and January; also in February if the hydrologic year-type is assessed to be Above Normal and Wet according to the Sacramento 40-30-30 Index.

- **VAMP-period Export Reduction (April 15–May 15):**

  Definition: Reduce exports to a target-restriction level during the VAMP period, regardless of the export level under the Regulatory Baseline; target depends on San Joaquin River flow conditions.

  Trigger: All years. Taking action during the VAMP period has been an EWAT high priority in 2001–2007 and is, therefore, modeled as a high priority.

- **Pre-VAMP "Shoulder-period" Export Reduction (April –April 15):**

  Definition: Extend the target-restriction level applied for VAMP period into the April 1-April 15 period.

  Trigger: It was not simulated to occur based on actions implemented by EWAT from WY2001–2007 and in the foreseeable future.

- **Post-VAMP "Shoulder-period" Export Reduction (May 16–May 31):**

Definition: Extend the target-restriction level applied for VAMP period into the May 16-May 31 period.

Trigger: In any May if collateral exceeds debt at the start of May.

- **June Export Reduction:**

  Definition: Steadily relieve the constraint on exports from the target-restriction level of the Post-VAMP period to the June Export-to-Inflow constraint level. Complete this steady relief on constraint during a 7-day period.

  Trigger: If the Post-VAMP “Shoulder-period” Export Reduction was implemented and if collateral exceeds debt at the start of June.

The following assets are included in the OCAP BA modeling:

- Allowance for Carryover Debt (Replacing “One-Time Acquisition of Stored-Water Equivalent” defined in the CALFED ROD)
- Water Purchases, North and South of Delta
- 50 percent Gain of SWP Pumping of (b)(2)/ERP Upstream Releases
- 50 percent Dedication of SWP Excess Pumping Capacity (i.e., JPOD)
- July-September Dedicated Export Capacity at Banks (additional 500 cfs capacity)
- Source shifting and dry/wet exchange operations are represented (for the Full EWA simulation, but not the Limited EWA)

The role of these fixed and operational assets in mitigating the effects of EWA actions depends on operational conditions and is ascertained dynamically during the simulation. On the issue of the one-time acquisition of stored-water equivalent, the CALFED ROD specified the acquisition of initial and annual assets dedicated to the EWA, and EWA was to be guaranteed 200 thousand acre-feet (taf) of stored water SOD. This SOD groundwater bank was excluded in the CalSim-II studies for OCAP BA given its absence in actual EWAT operations from WY2001–2007. Since development of this asset has been delayed, EWAT developed a replacement asset (i.e., allowance for carryover debt and subsequent debt spilling) and operational procedures for managing this asset. OCAP BA modeling reflects EWAT guidelines for carrying over and spilling debt in the case of debt situated at SWP San Luis.

The impacts of actions on system operations are assessed in the OCAP BA modeling as EWA debt. Debt is defined as a reduction in project deliveries and/or storage relative to the EWA baseline (i.e., results from Step 5). CalSim-II tracks three general types of EWA debt:

- Deliveries to contractors SOD
- Storage levels SOD
- Storage levels NOD

Occurrence of SOD deliveries, debt, and subsequent failure to immediately pay back this debt, is an indicator that the simulated EWA program’s assets are not in balance with the assumed actions. Occurrence of storage debt does not require immediate debt management.

Carried-over SOD storage debt is simulated to be managed through either: (1) direct dedication of assets, or (2) debt spilling. Dedication of assets involves transferring the accumulated purchases and variable assets from EWA San Luis into the projects' shares of San Luis to repay impacts caused by this year's actions and/or carried-over impacts from last year. The second tool, debt spilling, involves elimination of carried-over SOD debt at SWP San Luis assuming that several conditions were met at the end of the previous month (as described by EWAT):

- There was remaining capacity at Banks
- There was surplus water in the Delta that could have been exported
- The sum of end-of-month debt and stored water at SWP San Luis exceeded the sum of storage capacity and the "Article 21 deficit" (Figure 9-3) an Article 21 deficit represents demand minus what was delivered
- There was carried-over debt left to be spilled at SWP San Luis
- There was carried-over debt left to be spilled at SWP San Luis

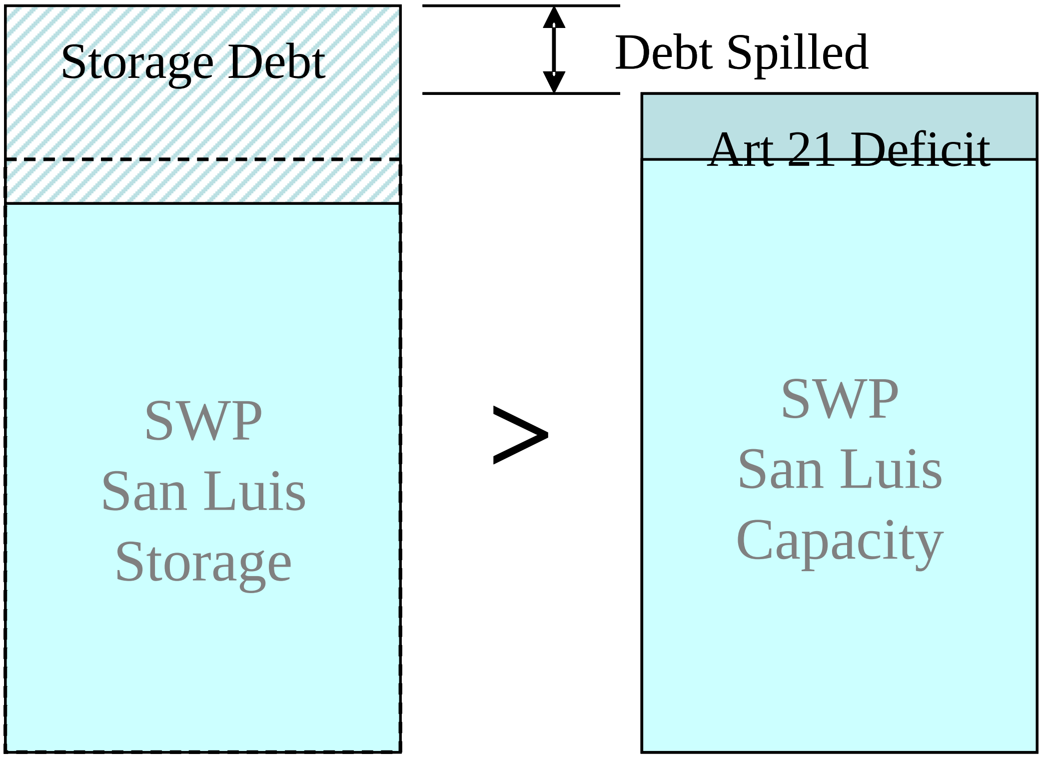

Figure 9-3 Conditions for Spilling Carried-over Debt at SWP San Luis in CalSim-II
Because the Regulatory Baseline cannot exceed SWP San Luis Capacity (i.e., the dashed line in Stack A), then the debt above this capacity line must be carried-over debt. Therefore, this spill tool will only be applicable to erasing carried-over debt and will not affect "new" debt conditions from this year's actions.
Spill amount is limited by the availability of excess capacity at Banks and surplus water in the Delta.

Limited EWA

The following actions are simulated in the OCAP BA modeling for Limited EWA fishery purposes:

- **VAMP-period Export Reduction (April 15–May 15):**

Definition:	Reduce exports to a target-restriction level during the VAMP period, only up to the amount covered by available assets in storage and available assets through Yuba Accord. Otherwise target depends on San Joaquin River flow conditions.
Trigger:	All years. Taking action during the VAMP period has been an EWAT high priority in 2001–2007 and is, therefore, modeled as a high priority.

- **Post-VAMP "Shoulder-period" Export Reduction (May 16–May 31):**

Definition:	Extend the target-restriction level applied for VAMP period into the May 16-May 31 period.
Trigger:	In any May, if assets are remaining after VAMP actions.

The following assets are included in the Limited EWA OCAP BA modeling:

- Water Purchases, Yuba Accord
- 50 percent Gain of SWP Pumping of (b)(2)/ERP Upstream Releases
- 50 percent Dedication of SWP Excess Pumping Capacity (i.e., JPOD) for conveyance of EWA purchase or delta surplus outflow
- July-September Dedicated Export Capacity at Banks for conveyance of EWA purchase or delta surplus outflow (an additional 500 cfs capacity)

CalLite

The CalLite tool is a rapid and interactive screening tool that simulates California's water management system for planning purposes. The CalLite tool is based on CalSim-II's 82 years of hydrologic inputs and logic using a simplified CalSim-II network which simulates, on a monthly time-step, CVP and SWP system conditions. "CalLite simulates the hydrology of the Central Valley, reservoir operations, project operations and delivery allocation decisions, Delta salinity responses to river flow and export changes, and habitat-ecosystem indices." (Munévar et al., 2008). The CalLite tool features:

- Rapid simulation evaluation (approximately 5 minutes depending on the scenario)
- User friendly Graphical User Interface (GUI)
- Flexible selection of policy alternatives or mode of simulation
- Pre-packaged post processing tools for output evaluation and alternative comparisons
- Cross-over of resources with CalSim-II data and logic

The following aspects of the CalLite model highlight areas where the model is coarser than the CalSim-II model to achieve the features listed above. The extent of the CalLite model reaches from northern California's Central Valley south to the Sacramento and San Joaquin Delta where the model terminates at the CVP and SWP Dos Amigos facility. All major CVP and SWP storage and conveyance facilities are included in the CalLite model. For the interim, the San Joaquin River Basin is simulated as a fixed time-series from CalSim-II results, while development is in progress. Differences between the CalSim-II and CalLite model are found in the aggregation of demands and hydrology inputs (accretions and depletions). The model represents "base" regulatory protection measures of SWRCB D-1641, allowing for screening additional policy proposals to augment above the "base" condition.

CalLite focuses on two specific areas which are not simplified "1) aspects governing operation and control of Delta facilities, water quality, channel flows, and ecosystem indicators; and (2) delivery allocation procedures for the CVP and SWP" (Munévar et al., 2008). The Delta is represented in an equivalent level of detail as the CalSim-II model. The CVP and SWP allocation procedures are also enhanced with an embedded module that more closely mimics the allocation forecasting process. In addition, this application has focused on the influence of uncertain hydrologic conditions in the allocation decision-making process.

The purpose of the CalLite tool for the OCAP BA is to screen and evaluate proposed Sacramento-San Joaquin Delta management actions for delta smelt and anadromous fish protection. This tool is well suited to quickly examine the tradeoffs of conflicting objectives for multiple alternatives. "CalLite is not a replacement for existing models, but rather is informed by the data and results of existing models and allows users to explore the future water management actions, improve understanding, and support more stakeholder-involved decision-making." (Munévar et al., 2008). Hence, interactive screening workshops define criteria that are then implemented in the more detailed planning model (CalSim-II) for final simulation. The screening process and selected results of alternative management scenarios requested by USFWS, NMFS and DFG are presented in Appendix V

Delta Hydrodynamic Modeling Methods

The objective of the hydrodynamic model, DSM2, is to simulate the Sacramento-San Joaquin River Delta (Delta) given monthly CVP and SWP project operations from the CalSim-II model results. These results provide flow, velocity, salinity, and particle movement (described below) in the Delta. DSM2 Old and Middle River flow results, an index for Delta fisheries, are used in the determination of the biological effects analysis. These results are also examined in a comparative evaluation because monthly output from the CalSim-II model is used as input to the DSM2 model.

DSM2

The DWR Delta Simulation Model Version 2 (DSM2) was used to simulate the flow, velocity, and particle movement in the Delta (Figure 9-4). DSM2 consists of three one-dimensional modules that simulate the dynamic tidal hydraulics, water quality, and particle movement in a network of riverine channels. The DSM2 modules used for the OCAP-BA were the hydrodynamics module Hydro, and particle tracking module PTM. DSM2 was developed by

DWR in the early 1990's. Since its introduction DSM2 has been used for many projects. It has also been continually improved upon. Some of the most recent enhancements have been:

- Incorporation of a database to control and archive study input parameters,
- Operable gates that allow the model to operate gates in based on a hydrodynamic condition.

DSM2-Hydro is a one dimensional hydrodynamics module that simulates unsteady, open channel flow, along with open water areas, gates and barriers. The Hydro module simulates flow, velocity and water elevations every 15 minutes for a little over 500 channels that represent the Delta channels. The simulated flow, velocity and water elevations are then used to drive the water quality and particle tracking simulations. These hydrodynamic parameters can also be pulled out for individual locations and analyzed. DSM2-PTM is a particle-tracking module that simulates the transport and fate of neutrally buoyant particles in the Delta channels. The module uses velocity and water elevation information from DSM2-Hydro to simulate the movement of virtual particles in the Delta. The movement of particles is tracked on a 15-minute time-step throughout the simulation. If a particle leaves the Delta system by way of an export, diversion, or through any other model boundary, this information is logged for latter analysis and termed the "fate" of the particle. The model grid can also be broken up into groups and the percentage of particles in each group can also be logged and analyzed.

DSM2 models all of the major rivers and waterways in the Sacramento – San Joaquin Delta. The model simulates these rivers and waterways in the Delta starting from the Sacramento River at I Street in the north, and the San Joaquin River at Vernalis in the south, to Benicia Bridge in the west. Major inflows to the model include the Sacramento River, San Joaquin River, Mokelumne River, Cosumnes River, Calaveras River, and Yolo Bypass. Major exports and diversions include Banks Pumping Plant, Jones Pumping Plant, North Bay Pumping Plant, and Contra Costa intake at Old River and Rock Slough. In addition to these inflows and diversions there is also a representation of Delta Island Consumptive Use (DICU), which are the agriculture diversions and return flows throughout the Delta. At the Benicia Bridge is the Martinez stage boundary where a historically based stage is defined every 15 minutes throughout the simulation.

For this effort DSM2-Hydro was used to evaluate the changes in flow and velocity in specific channels and regions of the Delta. DSM2-PTM was used to evaluate the effect of these changes on particle movement in the Delta. Both of the modules were used to evaluate conditions for water-years 1976 through 1991. This period has been traditionally selected because it offers a good mix of water year classifications as well as including an extreme critical year (1977), and extreme wet year (1983).

DSM2-Hydro used monthly operations from the individual CalSim-II simulations as input. The inflow to DSM2-Hydro included the Sacramento River, Yolo Bypass, Mokelumne River, Cosumnes River, Calaveras River and San Joaquin River flows. The exports and diversions included Banks Pumping Plant, Jones Pumping Plant, Contra Costa Water District diversions at Rock Slough and Old River at Highway 4, and North Bay Pumping Plant. Additionally Delta Island Consumptive Use (DICU) was also modeled (Mahadevan 1995). A 15 minute adjusted astronomical tide (Ateljevich 2001a) was used to drive the Martinez tidal boundary.

As described in Appendix F, some pre-processing of monthly CalSim-II flows was needed before DSM2-Hydro could appropriately characterize the system. Since CalSim-II provides monthly flows, and DSM2-Hydro is a 15 minute model some disaggregation and smoothing of data is required to transition from month to month stepwise flows. The Vernalis Adaptive Management Program (VAMP) period was also pre-processed from a monthly average to a daily average in order to include the pulse flows and export cut backs associated with VAMP which typically starts on April 15 and ends May 15.

DSM2 model assumptions can also be modified for Delta Temporary Barriers Project (TBP) and the South Delta Improvements Program (SDIP) Stage 1, permanent gates.

DSM2-PTM used the hydrodynamic information from DSM2-Hydro in order to simulate the movement of particles in the Delta. PTM simulates the movement of neutrally buoyant particles, and so if one can assume that a fish larvae behaves similar to a neutrally buoyant particle then the effects can be evaluated. For this reason, particles were injected every month and then tracked to determine the fate for each month. The particles were counted when they enter the exports, diversions and when they pass Chipps Island in the western Delta. The particles remaining in the Delta are then reported as being in the northern or southern Delta.

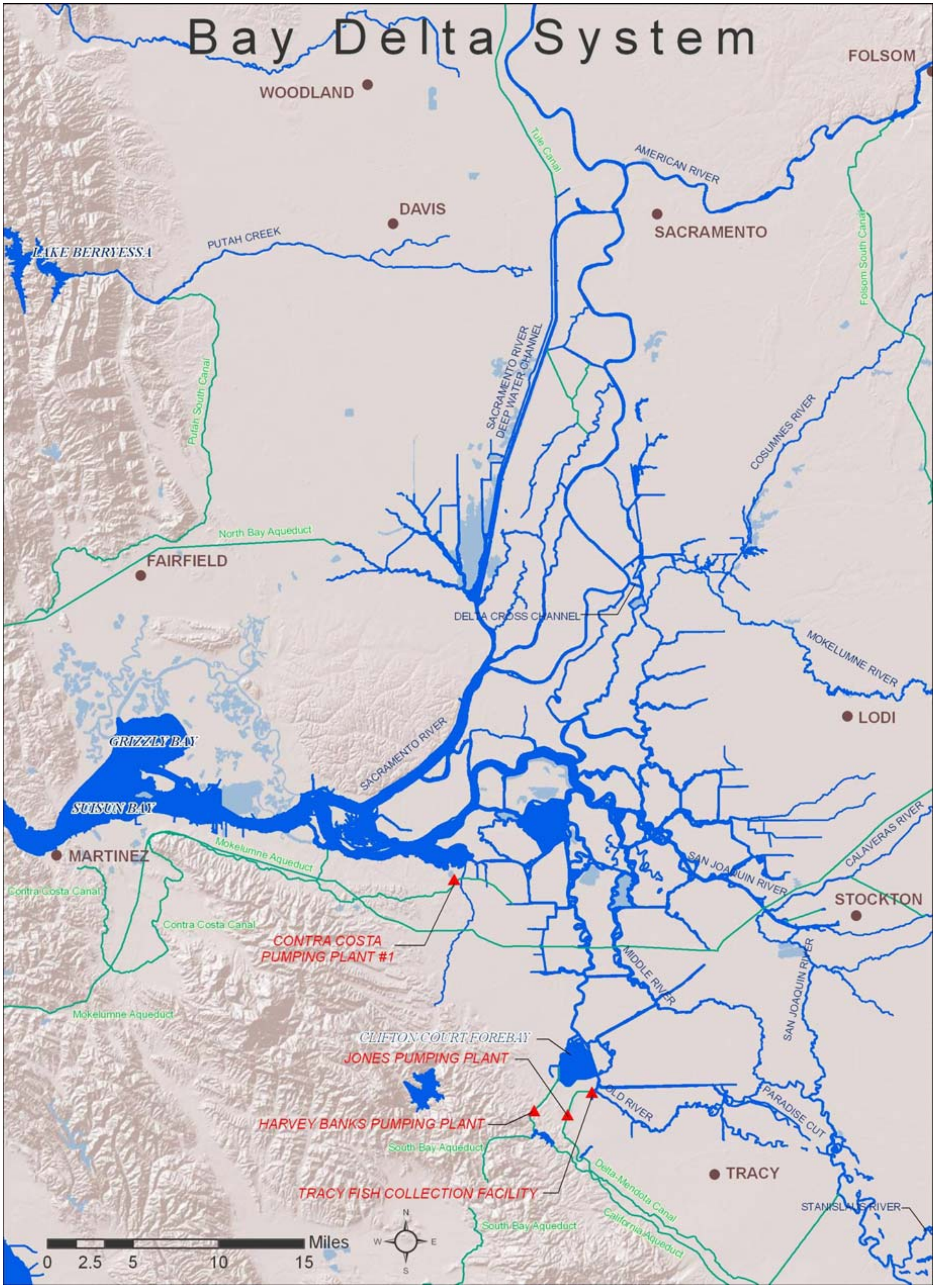

Figure 9-4 General spatial representation of the DSM2 network.

Temperature Modeling Methods

The objective of the temperature models is to assist in the fisheries impact evaluations of the various CVP/SWP operations studies. The Reclamation temperature model was used to estimate temperatures in the Trinity, Sacramento, American, and Stanislaus River systems. In addition, daily temperature simulation was performed on Clear Creek and the upper Sacramento River system using the SRWQM model. Refer to the FERC BO for a temperature evaluation on the Feather River. The joint DWR/Reclamation simulation model CalSim-II provided monthly CVP/SWP project operations input to the temperature model for an 82-year hydrologic period (WY1922-2003). All three temperature model reaches are spatially represented in Figure 9-5 Because of the CalSim-II Model’s complex structure, CalSim-II, flow arcs were combined at appropriate nodes to ensure compatibility with the temperature models.

Reclamation Temperature Model

The reservoir temperature models simulate monthly mean vertical temperature profiles and release temperatures for Trinity, Whiskeytown, Shasta, Folsom, New Melones, and Tulloch Reservoirs based on hydrologic and climatic input data. The temperature control devices (TCD) at Shasta, and Folsom Dams can selectively withdraw water from different reservoir levels to provide downstream temperature control. The TCDs are generally operated to conserve cold water for the summer and fall months when river temperatures become critical for fisheries. The models simulate the TCD operations by making upper-level releases in the winter and spring, mid-level releases in the late spring and summer, and low-level releases in the late summer and fall.

Temperature changes in the downstream regulating reservoirs – Lewiston, Keswick, Natomas, and Goodwin – are computed from equilibrium temperature decay equations in the reservoir models, which are similar to the river model equations. The river temperature models output temperatures are listed in Table 9-2.

Table 9-2 Reclamation Temperature Model Key Output Locations

RIVER OR CREEK SYSTEM	LOCATION
TRINITY RIVER	Trinity Dam
	Lewiston Dam
	Douglas City
	North Fork
CLEAR CREEK	Whiskeytown Dam
	Above Igo
	Below Igo
	Mouth

RIVER OR CREEK SYSTEM	LOCATION
AMERICAN RIVER	Folsom Dam
	Nimbus Dam
	Sunrise Bridge
	Cordova Park
	Arden Rapids
	Watt Avenue Bridge
	American River Filtration Plant
	H Street
	16th Street
	Mouth
SACRAMENTO RIVER	Shasta Dam
	Keswick Lake above Spring Creek Tunnel
	Spring Creek Tunnel
	Keswick Dam
	Balls Ferry
	Jellys Ferry
	Bend Bridge
	Red Bluff
	Vina
	Butte City
	Wilkins Slough
	Colusa Basin Drain
	American River
	Freeport
STANISLAUS RIVER	New Melones Dam
	Goodwin Dam
	Tulloch Dam

RIVER OR CREEK SYSTEM	LOCATION
STANISLAUS RIVER	Knights Ferry
	Orange Blossom
	Oakdale
	Riverbank
	McHenry Bridge
	Ripon
	Mouth

The river temperature calculations are based on regulating reservoir release temperatures, river flows, and climatic data. Monthly mean historical air temperatures for the 82-year period and other long-term average climatic data for Trinity, Shasta, Whiskeytown, Redding, Red Bluff, Colusa, Folsom, Sacramento, New Melones, and Stockton were obtained from National Weather Service records and are used to represent climatic conditions for the four river systems. Additional details of the Reclamation Temperature Model are located in Appendix H.

Sacramento River Water Quality Model (SRWQM) Temperature Model

A HEC-5Q model was developed and calibrated for the upper Sacramento River system, including Trinity Dam, Trinity River to Lewiston, Lewiston Dam, Clear Creek Tunnel, Whiskeytown Dam, Spring Creek Tunnel, Shasta Dam, Keswick Dam, Sacramento River from Keswick to Knights Landing, Clear Creek below Whiskeytown, Red Bluff Diversion Dam, Black Butte Dam, and downstream Stony Creek.

The water quality simulation module (HEC-5Q) was developed so that temperature could be readily included as considerations in system planning and management. Using system flows computed by HEC-5, HEC-5Q computes the distribution of temperature in the reservoirs and in stream reaches. HEC-5Q is designed for long-term simulations of flow and temperature using daily average hydrology and 6-hour meteorology. Vertically stratified reservoirs are represented conceptually by a series of one-dimensional horizontal slices or layered volume elements, each characterized by an area, thickness, and volume. The HEC-5Q model simulation approximates diurnal variations in temperature for a 6-hour time step. The model was calibrated for the period of January 1998 through November 2002, using temperature time series field observations at numerous locations in the Trinity River, Clear Creek, and upper Sacramento River.

HEC-5Q is used to evaluate options for coordinating reservoir releases among projects to examine the effects on flow and water temperature at specified locations in the system. The model is used to evaluate instream temperatures at critical locations in a system, and examination of the potential effects of changing reservoir operations or water use patterns on temperature. Reservoirs, such as Shasta Lake, equipped with selective withdrawal structures can be simulated using HEC-5Q to determine operations necessary to meet water quality objectives downstream.

For this analysis, the Temperature Control Device (TCD) algorithm was modified to operate the Shasta Dam spillway, flood control outlets, and TCD gates to meet tailwater temperature targets. Key reporting locations are listed in Table 9-3.

Table 9-3. SRWQM Model Key Output locations

RIVER OR CREEK SYSTEM	LOCATION
Shasta Dam	Tailwater
Lewiston	Fish Hatchery
Spring Creek	Powerhouse
Sacramento River	Below Keswick Dam
	Clear Creek Confluence
	Balls Ferry
	Jellys Ferry
	Bend Bridge
	Red Bluff Diversion Dam
	Tehama
	Woodson Bridge
	Hamilton City
	Butte City
	Colusa
	Above Colusa Basin Drain
Black Butte Dam	Black Butte Dam
Stony Creek	Tehama Colusa Canal

Additional information is available in Appendix H.

Oroville Facilities Water Temperature Modeling

The operations on the Feather River for the Oroville Facilities are currently being covered under a separate Section 7 ESA consultation process for the Federal Energy Regulatory Commission (FERC) relicensing process. The draft NMFS BO is scheduled for release in late May 2008. Oroville Facilities water temperature modeling information is being provided for information purposes only.

Water temperature modeling supporting the Oroville Facilities FERC Relicensing utilized a suite of five models linked through a central database. The five models included reservoir simulations of Oroville Reservoir, the Thermalito Diversion Pool, the Thermalito Forebay, and the Thermalito Afterbay, and a river model of the Feather River between the Thermalito Diversion Dam and the Sacramento River confluence. All models were 1-dimensional models operating on an hourly timestep; the reservoirs were simulated as a series of vertically segregated, one-meter thick layers, the Feather River was simulated as a series of depth-averaged river segments with cross-section data from a calibrated flow-stage model, based on hydrologic and climactic input data. The modeling suite included iteration to meet water temperature objectives at the two Feather River water temperature compliance locations, the Feather River Fish Hatchery (FRFH) and Robinson Riffle. Operations for the water temperature objectives incorporated a range of temperature control actions including: curtailment of pumpback operations, elimination of hydropower peaking operations, removal of shutters on the Hyatt Pumping-Generating Plant intake, increasing the flow in the Low Flow Channel, and making releases through the Oroville Dam river valve. The water temperature modeling suite provided the following data output:

-Water temperatures in 100 river segments on the Feather River between the Thermalito Diversion Dam and the Sacramento River confluence. Several key river segments were used in evaluation, two of which, the FRFH and Robinson Riffle, were used to determine water temperature compliance (see Appendix J for key output locations).

-Reservoir profiles and release temperatures for Oroville Reservoir, the Thermalito Diversion Pool, the Thermalito Forebay, and the Thermalito Afterbay

-Agricultural diversion temperatures at four locations in the Thermalito Afterbay

-Water temperature in the Feather River Fish Hatchery

Hydrologic and climactic input data were based on historical records from the Durham and Nicolaus stations of the California Irrigation Management Information System (CIMIS) and extrapolated out for a 73 year (1922-1994) period of record based on available historical Sacramento Valley data. DWR collected field data for the model calibration and verification from March 28, 2002 through December 30, 2003. Calibration of the model was performed with data from August 11, 2002 to December 30, 2003, including two occurrences of the most critical period for water temperature management, September through October. The model was verified against conditions from the remaining time period of the available data, March 28 through July 15, 2002. It is anticipated that additional model calibration and verification will be included in future modeling efforts for the implementation phase of the Oroville Facilities Relicensing. Additional information about the water temperature model can be found in Appendix J and Appendix K.

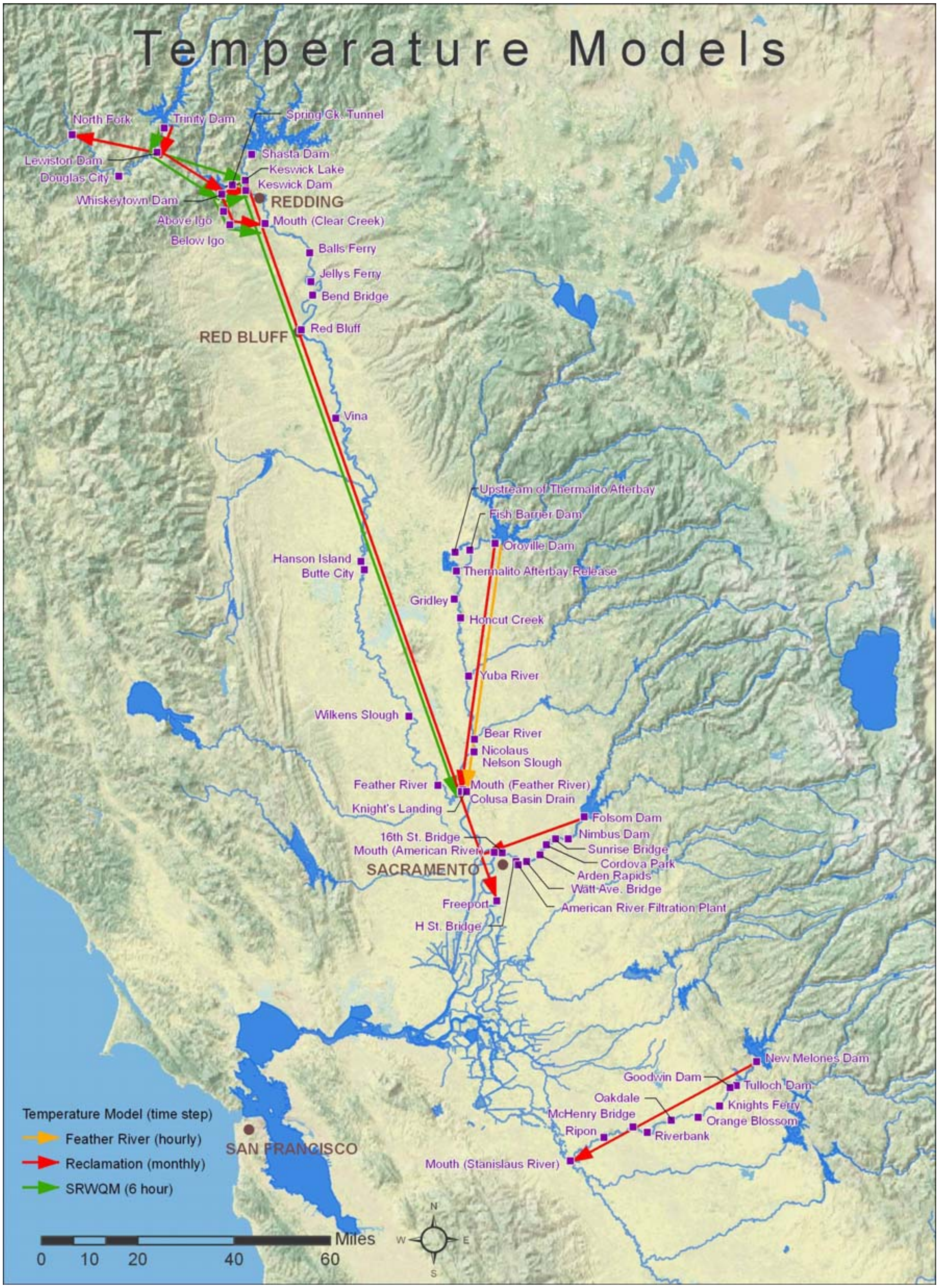

Figure 9-5 General spatial representation of the temperature model networks.

Salmon Mortality and Life Cycle Modeling Methods

The objective of the salmon mortality and life cycle models is to simulate salmon losses and population dynamics. These results quantify the change of salmon loss and population dynamics as compared amongst the model scenarios. The salmon models use simulated temperature results and CVP/SWP operation results from CalSim-II, described above. The three models applied to the OCAP BA are the Reclamation salmon mortality model, SALMOD, and the Interactive Object-Oriented Salmon Simulation (IOS) life cycle model for winter-run salmon. Each of the three salmon models is spatially represented in Figure 9-6.

Reclamation Salmon Mortality Model

The Reclamation salmon mortality model computes salmon spawning losses in the four rivers, Trinity, Sacramento, American, and Stanislaus, based on the Reclamation Temperature Model estimates. The model uses DFG and FWS data on Chinook salmon spawning distribution and timing in the five rivers (Reclamation 1991, Loudermilk 1994, and Reclamation 1994) Temperature-exposure mortality criteria for three life stages (pre-spawned eggs, fertilized eggs, and pre-emergent fry) are used along with the spawning distribution data and output from the river temperature models to compute percents of salmon spawning losses. Temperature units (TU), defined as the difference between river temperatures and 32°F, are calculated daily by the mortality model and used to track life-stage development. Eggs are assumed to hatch upon exposure to 750 TUs following fertilization. Fry are assumed to emerge from the gravel after exposure to 750 TUs following egg hatching into the pre-emergent fry stage. The temperature mortality rates for fertilized eggs, the most sensitive life stage, range from 8 percent in 24 days at 57°F to 100 percent in 7 days at 64°F or above (Reclamation, 1994). Most salmon spawning generally occurs above the North Fork on the Trinity River, above Red Bluff on the Sacramento River main stem for all four Chinook salmon runs, above Watt Avenue on the American River, and above Riverbank on the Stanislaus River. Fall-run salmon spawning usually occurs from mid-October through December, peaking about mid-November. Winter-run salmon usually spawn in the Sacramento River during May-July, and spring-run salmon during August-October. Additional information on the Reclamation mortality model is located in Appendix L.

SALMOD

SALMOD is a computer model that simulates the dynamics of freshwater salmonid populations. SALMOD was applied to this project because the model had been previously used on the upper Sacramento River (from Keswick Dam down to Battle Creek), and because a thorough review and update of model parameters and techniques on the Klamath River enabled a smooth transfer of relevant model parameters to the Sacramento River (Bartholow, 2003). The study area for this analysis covers a 53-mile (85-kilometer) stretch of the Sacramento River from Keswick Dam to just above the RBDD. Keswick Dam forms the current upstream boundary of anadromous fish migration in the Sacramento River, and the RBDD marks the current downstream limit of habitat that has been consistently classified by mesohabitat type and evaluated using the Physical Habitat Simulation System (PHABSIM) and River 2D. The study area terminates at this point because RBDD is operated with gates that can be raised or lowered that alter the inundation pool’s hydraulics. This pool has not been modeled for habitat value. SALMOD functions to integrate microhabitat and macrohabitat limitations to a population through time and space. The term “habitat limitations” does not imply that freshwater habitat is the ultimate factor limiting the populations, but that habitat constraints may reduce populations while other factors, such as ocean conditions or fishing pressure, may be the ultimate limiting factor.

SALMOD simulates population dynamics for all four runs of Chinook salmon in the Sacramento River between Keswick Dam and RBDD. SALMOD presupposes egg and fish mortality are directly related to spatially and temporally variable microhabitat and macrohabitat limitations, which themselves are related to the timing and volume of streamflow and other meteorological variables. SALMOD is a spatially explicit model in which habitat quality and carrying capacity are characterized by the hydraulic and thermal properties of individual mesohabitats, which serve as spatial computation units in the model. The model tracks a population of spatially distinct cohorts that originate as eggs and grow from one life stage to another as a function of water temperature in a computational unit. Individual cohorts either remain in the computational unit in which they emerged or move, in whole or in part, to nearby units.

Model processes include spawning (with redd superimposition), incubation losses (from either redd scouring or dewatering), growth (including egg maturation), mortality due to water temperature and other causes, and movement (habitat and seasonally induced). SALMOD is organized around physical and environmental events on a weekly basis occurring during a fish’s biological year (also termed a brood year), beginning with adult holding and typically concluding with fish that are physiologically “ready” to begin migration towards the ocean. Input variables, represented as weekly average values, include streamflow, water temperature, and number and distribution of adult spawners. The study area is divided into individual mesohabitats (i.e., pool, riffle, and run) categorized primarily by channel structure and hydraulic geometry, but modified by the distribution of features such as fish cover. Thus, habitat quality in all computational units of a given mesohabitat type changes similarly in response to discharge variation. Habitat type and streamflow determine the available habitat area for a particular life stage for each time step and computational unit. Habitat area (quantified as weighted usable area, or WUA) is computed from flow: microhabitat area functions developed empirically or by using PHABSIM (Milhous et al., 1989) or River 2D for the reach from Keswick Dam to Battle Creek and a two dimensional hydraulic model for Battle Creek to RBDD. Habitat capacity for each life stage is a fixed maximum number of salmon per unit of habitat area available estimated from literature or empirical data. Thus, the maximum number of individuals that can reside in each computational unit is calculated for each time step based on streamflow, habitat type, and available microhabitat. Fish in excess of the habitat’s capacity must move to seek unoccupied habitat elsewhere. Fish from outside the model domain (from tributary production) were also added to the modeled stream as fry and juveniles.

Flow and water temperature time series values were derived from the CalSim-II and HEC-5Q models. Data for each day corresponded to the weekly average conditions for that day forward. Data covered the period 1921 to 2003, a total of 82 water-years. Additional information on the SALMOD model is located in Appendix P.

Interactive Object-Oriented Salmon Simulation (IOS) Winter-Run Life Cycle Model

The IOS Winter-Run Life Cycle model was used to evaluate the influence of different Central Valley water operations on the life cycle of Sacramento River winter-run Chinook salmon over an 80 year period using simulated flow and water temperature inputs. The IOS model was designed to serve as a quantitative framework for estimating the long-term response of Sacramento River Chinook populations to changing environmental conditions (e.g. river discharge, temperature, habitat quality at a reach scale). Life cycle models are well-suited for such evaluations because they integrate survival changes at various life stages, across multiple habitats, and through many years. The IOS model was seeded with 5,000 spawners for the first four years then allowed to cycle through multiple generations during years 1923-2002.

Reach specific, daily (disaggregated CalSim-II) discharge and daily HEC-5Q water temperature provided the basic inputs for model runs. In addition, monthly average Delta conditions (inflow, exports, DCC operations, temperature) were provided by CalSim-II. Other model settings were set specifically for this analysis and at constant values throughout the 80-year run of the IOS model. The use of constant values for parameters with little uncertainty or with lesser management significance is desirable because it simplifies the model and facilitates easier interpretation of results.

The effect of different water operation scenarios on the Sacramento River winter-run Chinook salmon population was evaluated by comparing abundance and survival trends at various life stages among the three runs of the IOS Model. The annual abundance of returning spawners and juveniles out-migrating past RBDD were reported for each model run. Trends in survival through time at various life stages were examined to explain patterns seen in yearly escapement under each water operation scenario. Average differences in winter-run survival between water operation scenarios were translated into average differences in annual escapement to better evaluate the potential impact each water operation scenario has on the winter-run abundance in the Sacramento River. Finally, typical monthly spatial distribution of juvenile salmon during model runs was reported. Additional details of the IOS model are also presented in Appendix N.

Figure 9-6 General spatial representation of the salmon model networks.

Climate Change and Sea Level Rise Sensitivity Analysis Modeling Methods

The approach selected for the climate change analysis is being referred to as "Sensitivity Analysis", which includes a quantitative analysis of implications for future CVP and SWP operations under a range of potential climates in order to illustrate how the OCAP BA future operational baseline is sensitive to the future climate assumptions. With respect to the OCAP BA, the Sensitivity Analysis is focused on exploring how climate change might affect:

- Operational conditions of interest (e.g., storage, deliveries, flows, reservoir and river water temperature, Delta water levels and salinity),
- Described statistically during long-term, by year-type, or during drought-periods,
- Assessed at a 2030 look-ahead consistent with the consultation horizon.

The chosen approach for incorporating climate change information calls for re-evaluating the OCAP BA future operations baseline given assumptions consistent with different future climates, representing a range of potential future climates. These re-evaluated results are then compared against baseline results represented under "recent" climate. The comparison of results illustrates the sensitivity of the operations condition to the future climate assumption. The re-evaluations will focus on regional climate change defined in terms of monthly temperature and precipitation changes translated into surface water supply changes, and to global climate change defined in terms of sea level rise affecting Delta conditions. CVP and SWP operational policies are not modified to respond to the future climates and sea level rise.

To define a range of future climate possibilities, four projections were selected to encapsulate a reasonable range of projected climate conditions over the study region. The four projections will were selected based on how they collectively represent a range of:

- "lower" to "greater" temperature changes (which correspond to "*less warming*" to "*more warming*" over California),
- combined with a range of "lower" to "greater" precipitation magnitude changes (which correspond to "*drier*" to "*wetter*" conditions).

Projections selection depends on several factors that are study-specific:

- **Factor 1 –** Look-ahead horizon relevant to this study
- **Factor 2 –** Climate metric relevant to the study's operational questions
- **Factor 3 –** Location representative of the study region
- **Factor 4 –** Projected "Change Range" of Interest, a subjective choice on how much projections spread to represent.

Climate projection selection for the OCAP BA sensitivity analysis then proceeds with a four-step implementation process based on the four selection factor decisions.

- **Step 1**: Survey climate projections data from the Downscaled Climate Projections (DCP) archive spanning the periods of selection factor decision #1, reported at the location of selection factor decision #3.
- **Step 2:** For base and future periods (selection factor decision #1), compute mean annual Temperature (T) and Precipitation (P) conditions for each of the 112 projections surveyed in Step 1. "Mean annual" is the climate metric of selection factor decision #2. Next, compute change in mean annual T and P (ΔT and ΔP, change respectively) from base to future period, by projection, and evaluate the rank-distribution of changes among the projections for each variable. Identify rank-percentile changes for each variable based on selection factor decision #4 (i.e. focusing on 10th and 90th percentile changes for both variables).
- **Step 3**: Switch focus to "projections spread", and evaluate the plot of ΔT versus ΔP. Overlay rank-percentile changes identified for each variable in Step 2. The intersection of the $\Delta T_{10\%\text{-tile}}$ and $\Delta T_{90\%\text{-tile}}$ with $\Delta P_{10\%\text{-tile}}$ and $\Delta P_{90\%\text{-tile}}$ formulates a two-variable "change range of interest."
- **Step 4:** Choose 4 projections having paired projected changes (i.e. $\{\Delta T, \Delta P\}$) that most closely match the four vertices of the two-variable "change range of interest."

CalSim-II hydrology inputs are modified to reflect the 4 projected changes in temperature and precipitation. Sea level rise assumptions are also implemented and evaluated using the DSM2 hydrodynamic model. See Appendix R for additional details.

Sensitivity and Uncertainty

Sensitivity and uncertainty analyses are typical testing procedures used to assess model performance. The tests provide useful information to assist decision makers who are using results from models. The purposes of the two analyses include:

1. Sensitivity Analysis: Identify parameters and input data which have a major impact to the system, and
2. Uncertainty Analysis: Understand the confidence of simulated results.

The CalSim-II sensitivity results are useful in tandem with the uncertainty results to affirm model performance, identify sensitive variables, and understand a likely band of modeled uncertainty. In this evaluation, sensitivity and uncertainty analyses are limited to the CalSim-II model.

These analyses examine a limited perspective of uncertainty and do not evaluate all aspects of uncertainty. Uncertainty of engineered water resources systems is generally categorized as hydrologic, hydraulic, structural, and economic (Mays and Tung, 1992). Ecosystems are an additional category of uncertainty to consider. Cumulative uncertainty or total uncertainty, defined here, is the collective simulated uncertainty due to the application of tiered modeling and to the categories mentioned above. Sensitivity and uncertainty to hydrology, water demands, and Delta compliance standards are addressed in the analysis for CalSim-II. However, a rigorous uncertainty evaluation including tiered modeling, hydraulic, structural, economic, ecosystem, and other drivers was not attempted due to the level of effort required for this type of analysis. The methods, scope and evaluation of the CalSim-II sensitivity and uncertainty analyses are presented in Appendix W. Sensitivity and uncertainty results are presented in Appendix X.

The model results presented below and elsewhere (Chapters 10-13) are generated using models with uncertain information. The uncertainty of absolute results, as models build upon another with the tiered approach, is expected to increase. For example, the CalSim-II representation of the current operational conditions captures seasonal trends, frequencies and magnitudes well but imperfectly (see Appendix U). The uncertainty evaluation and historical comparisons should be considered in the evaluation of all of the simulated results presented in the OCAP BA.

Other Tools

Qualitative or quantitative tools which are, or could be, applied to the CVP and SWP systems but were not used in OCAP BA are also acknowledged. Some tools are in development or contained a component of incompatibility that could not be applied. These tools or processes should be considered for future evaluation when available or made compatible.

In early 2008 the California Department of Fish and Game introduced new conceptual models to better manage species and ecosystem responses. These models were not available for use during the development of this BA, however, they seem promising and should be considered in the future. The following are excerpts from the Delta Restoration Plan Species Life History Models Report (DFG, 2007) summarizing the DRERIP model and process:

> "*Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) will implement adaptive management by incorporating scientific evaluation of restoration actions in light of the current state of knowledge and restoration projects implemented to date. The DRERIP science input process is divided into four phases; (1) process design; (2) the development of species life history models and ecosystem element conceptual models; (3) the development and evaluation of proposed ERP actions; and (4) an analysis of the feasibility and prioritization of the actions.*
>
> *The California Department of Fish and Game, working with the CALFED Science Program and other CALFED agencies, is engaged in the development of a series of conceptual models for the Delta that can inform decision making regarding future conservation and restoration actions. The following provides general guidelines for the preparation of these species models, including how the models will be used, definitions of terms, information that should be included in each model, and a basic outline that should be followed. These guidelines have been amended following beta-testing of the overall Delta Restoration Plan (DRERIP) suite of models in order to facilitate vetting of likely restoration actions.*
>
> *The purpose of these guidelines is to promote consistency between the structure, format, and level of information contained within each species model. The guidelines are also intended to improve the application of the models, including linkages between the species models and related ecosystem element conceptual models being developed separately that describe natural processes, habitats, and stressors acting upon the population dynamics of the component species within the community."*

> *"The purpose of the species models is to describe the basic biology (life cycle and life history) of several key species, and to articulate explicitly the current state of knowledge regarding factors influencing their reproductive success, growth, and survival—the underlying population dynamics as we understand them. This information will necessarily direct appropriate restoration actions most efficiently, and forms the foundation for adaptive management within the CALFED ERP process. It is critically important that these models address the most appropriate outputs (outcomes) to define particular restoration actions and objectives towards long-term population viability of your particular species. This information includes a comprehensive treatment of the threats facing different lifestages of these species under different seasonal scenarios and conditions."*

> *"The DRERIP conceptual models follow a deterministic paradigm, using the DLO approach: drivers (D), linkages (L), and outcomes (O).* ***Drivers*** *are physical, chemical, or biological forces that control the species or system of interest.* ***Linkages*** *are cause-and-effect relationships between drivers and outcomes.* ***Outcomes*** *are response variables (such as reproductive success, growth, and mortality) that the conceptual model is attempting to explain. In the context of the DRERIP species conceptual models, "ultimate" outcomes reflect population-level responses to drivers."*

Other temperature models were also examined but not used during the development of the OCAP BA. Various water temperature models are available and applied to CVP Rivers and tributaries. These models represent a variety of geographic locations and temporal resolution. The simulation of water temperature in the OCAP BA captures short term variability (e.g. daily time-step) in the Clear Creek, Sacramento, and the Feather Rivers and a coarser time step elsewhere.

Other temperature models applied in the Central Valley include simulation of the American River (Reclamation) and the Stanislaus River (AD and RMA, 2002) at a sub-monthly time-step. However, daily and sub-daily disaggregation assumptions, testing, and verification were not available for these locations using the full 82 year CalSim-II data sets for the American and Stanislaus rivers. Tools simulating real-time temperature operations, such as optimizing cold water pool storage using CalSim-II data, were also not available. Supplemental historical temperature observations were evaluated to overcome these modeling limitations.

The treatment of temperature simulation is unequal amongst the basins presented in the BA. This is due in part to present data availability, inconsistency in model approach between agencies, model complexity, and computation time. For the short term, supplemental historical temperature observations are presented to overcome these modeling limitations (Appendix U). A long-term temperature model development plan including consistent spatial and temporal application for the CVP and SWP systems will be considered for future applications.

Modeling Studies and Assumptions

DWR and Reclamation developed a set of "Common Assumptions" (as part of CALFED Storage Project Investigations) for the purpose of developing an updated CalSim-II study to be used as a basis for comparing project alternatives. From the "Common Assumptions" CalSim-II model, ten CalSim-II studies (and one study from the previous 2004 BA modeling) have been developed to evaluate the effects of changes in future operations for the OCAP BA. The programs evaluated include: Freeport Regional Water Project, California Aqueduct and Delta-Mendota Canal Intertie, level of development (future demands), Yuba River Accord, Full Environmental Water Account (EWA) and Limited EWA, Red Bluff Diversion Dam, American River Flow Management, Sacramento River Reliability, South Delta Improvements Program (SDIP) Stage 1, and climate change and sea level rise.

Study assumptions and refinements have been made since the OCAP BA May 2008 documentation in response to external reviews and requests from the FWS. Study 3a and Study 6.0 now include simulations through the EWA step. CVP and SWP operational refinements have also been applied to Studies 7.0, 7.1, 8.0 and the 9.0 suite to better capture North-of-Delta and South-of-Delta balancing. A full list of model refinements is included in Appendix E.

The study scenarios were formed to capture the past assumptions, present, near-future, future, and future with an alternative climate conditions:

1. **Study 3a –** This study is repeated from the previous OCAP BA 2004 for comparative purposes. It represents a prior condition (a 2001 level of land use development) and simulates through the Environmental Water Account (EWA) simulation step. Study 3a also includes the Trinity Record of Decision (ROD) implementation.
2. **Study 6.0 –** This study represents the previous OCAP BA 2004 assumptions within the new CalSim-II model framework. Conditions for water demands, facilities, and water project-operational policy are duplicated, to the extent possible, to Study 3a. This study corresponds to an “existing” condition (developed to compare to the 2004 OCAP BA Study 3a, with a 2005 level of land use development) and simulates through the EWA step. This study is designed to compare to Study 3a and highlights differences due to model refinement.
3. **Study 6.1 –** This study represents the previous OCAP BA 2004 assumptions also within the new CalSim-II model framework. Conditions for water demands, facilities, and water project-operational policy are duplicated, to the extent possible, to Study 3a, but this is simulated only through the CVPIA (b)(2) step. This study is identical to Study 6.0 in the OCAP BA May 2008 issue and is included to emulate pre-Pelagic Organism Decline (POD) conditions. Study 6.1 is an imperfect representation of the pre-POD and supplemental analysis should be evaluated to compensate for this modeling limitation (discussed in Chapter 13: CVP and SWP Delta Effects). Study 6.1 results are presented in Appendix E.
4. **Study 7.0 –** This study forms the model to compare future proposed operations. Study 7.0 describes existing water demands, facilities, and water project operational policy, to the extent possible. It represents the today condition (a 2005 level of land use development) through the EWA simulation step.
5. **Study 7.1 –** This study represents water demands and policy for existing conditions, current and near-future facilities, and existing and near-future water project operational policy. It corresponds to the today condition (a 2005 level of land use development)

through the Limited EWA simulation step. Study 7.1 should be compared to Study 7.0 to determine the effect of near-future facilities and policies.

6. **Study 8.0 –** This study represents assumed water demands and policy for the future. It represents the future condition (a 2030 level of land use development) through the Limited EWA. Study 8.0 should be compared to Study 7.0 to determine the effect of future facilities and policies.
7. **Study 9.0-9.5 suite –** These studies constitute the future with climate change and sea level rise. It represents a conservative future condition (a 2030 level of land use development) for D-1641 WQCP. Studies 9.1-9.5 are identical to Study 8.0's D-1641 simulation step except:
    a. Climate modified hydrology, and
    b. Sea level rise.

   The sub-suite studies represent the range of temperature and precipitation explored for climate change. The Study 9.0 suite represents future condition as a separate study for sensitivity evaluation.

Compatible comparisons can be made with the following studies:

1. **Study 3a and Study 6.0 –** This comparison identifies the difference between model development/refinement since the OCAP BA 2004 (see Table 9-3 for CalSim-II model revisions). Appendix E presents the comparison between OCAP BA 2004 Study 3a and Study 6.0 CalSim-II results. Note there is no compatible comparison information on 6.1.
2. **Study 7.0 and Study 7.1 –** A comparison between Study 7.0 and Study 7.1 illustrates the change between the "Today" and "Near-Future" conditions. Where the "Near Future" contains the Limited EWA, South Delta Improvement Project Stage 1, Freeport Regional Water Project, and California Aqueduct/Delta Mendota Canal Intertie.
3. **Study 7.0 and Study 8 –** This comparison presents the change between the base model, "Today" and "Future" conditions. The "Future" contains the Limited EWA, the South Delta Improvement Project Stage 1, Freeport Regional Water Project, California Aqueduct/Delta Mendota Canal Intertie, and future water demands.
4. **Study 7.1 and Study 8.0 –** A comparison between Study 7.1, the "Near Future", and Study 8.0, the "Future" highlights the change in future water demands.

Table 9-4 shows the eleven studies developed for OCAP BA and generally how assumptions change. Table 9-5 shows the detailed assumptions of Studies 3a through 9.0. The latter table also illustrates specific operational changes regarding regulatory and operational rules.

Table 9-4 Summary of Assumptions in the OCAP BA Runs

	CVPIA 3406 (b)(2)	Level of Development	EWA	SDIP Stage 1	Freeport	Intertie	Climate and Sea Level Rise
Study 3a Today EWA	May 2003	2001	Full				
Study 6.0 Today EWA	May 2003	2005	Full				
Study 6.1 Today CVPIA (b)(2)	May 2003	2005					
Study 7.0 Today EWA	May 2003	2005	Full				
Study 7.1 Today Limited EWA	May 2003	2005	Limited	X	X	X	
Study 8.0 Future Limited EWA	May 2003	2030	Limited	X	X	X	
Study 9.0 Future D1641 SA Climate Change		2030		X	X	X	No Sea Level Rise
Study 9.1 Future D-1641		2030		X	X	X	1ft Sea Level Rise and 4" amplitude
Study 9.2 Future D-1641		2030		X	X	X	Wetter, Less Warming Climate Change with 1ft Sea Level Rise and 4" amplitude
Study 9.3 Future D-1641		2030		X	X	X	Wetter, More Warming Climate Change with 1ft Sea Level Rise and 4" amplitude
Study 9.4 Future D-		2030		X	X	X	Drier, Less Warming

	CVPIA 3406 (b)(2)	**Level of Developm ent**	**EWA**	**SDIP Stage 1**	**Freeport**	**Intertie**	**Climate and Sea Level Rise**
1641							Climate Change with 1ft Sea Level Rise and 4" amplitude
Study 9.5 D-1641 Future		2030		X	X	X	Drier, More Warming Climate Change with 1ft Sea Level Rise and 4" amplitude

Table 9-5. Assumptions for the Base and Future Studies

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
		OCAP BA 2004 Today CVPIA 3406 (b)(2) with EWA	**Today-OCAP BA 2004 Assumptions in Revised CalSim-II Model - EWA**	**Today-OCAP BA 2004 Assumptions in Revised CalSim-II Model - CVPIA (b)(2) - CONV**	**Today-Existing Conditions, (b)(2), EWA**	**Near Future-Existing Conditions and OCAP BA 2004 Consulted Projects, (b)(2), Limited EWA**	**Future - (b)(2), Limited EWA**	**Future Climate Change-D1641**	**Model Revisions since OCAP BA 2004**
OCAP Base model: Common Assumptions: Common Model Package (Version 8D) *"Same" indicates an assumption from a column to the left*									
Planning horizon		2001	2005[a]	Same	Same	Same	2030[a]	Same	
Period of Simulation		73 years (1922-1994)	82 years (1922-2003)	Same	Same	Same	Same	Same	Extended hydrology timeseries
HYDROLOGY								Inflows are modified based on alternative climate inputs[b]	Revised level of detail in the Yuba and Colusa Basin including rice decomposition operations
Level of development (Land Use)		2001 Level	2005 level	Same	Same	Same	2030 level[c]	Same	
Sacramento Valley (excluding American R.)									
	CVP	Land-use based, limited by contract amounts[d]	Same	Same	Same	Same	CVP Land-use based, Full build out of CVP contract amounts[d]	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	SWP (FRSA)	Land-use based, limited by contract amounts[e]	Same	Same	Same	Same	Same	Same	
	Non-project	Land-use based	Same	Same	Same	Same	Same	Same	
	Federal refuges	Firm Level 2	Same	Same	Recent Historical Firm Level 2 water needs[f]	Same	Firm Level 2 water needs[f]	Same	
American River									
	Water rights	2001[g]	Same	Same	2005[g]	Same	2025[g]	Same	
	CVP (PCWA American River Pump Station)	No project	Same	Same	CVP (PCWA modified)[g]	Same	Same	Same	
San Joaquin River[h]									Developed land-use based demands, water quality calculations, and revised accretions/depletions in the East-Side San Joaquin Valley
	Friant Unit	Regression of Historical Demands	Limited by contract amounts, based on current allocation policy	Same	Same	Same	Same	Same	
	Lower Basin	Fixed Annual Demands	Land-use based, based on district level operations and constraints	Same	Same	Same	Same	Same	
	Stanislaus River	New Melones Interim Operations Plan	Same	Same	Same	Draft Transitional Operations Plan[r]	Same	Same	Initial storage conditions for New Melones Reservoir

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
									were increased.
South of Delta									
	(CVP/SWP project facilities)	CVP Demand based on contracts amounts[d]	Same	Same	Same	Same	Same	Same	
	Contra Costa Water District	124 TAF/yr annual average	135 TAF/yr annual average CVP contract supply and water rights[i]	Same	Same	Same	195 TAF/yr annual average CVP contract supply and water rights[i]	Same	
	SWP Demand - Table A	Variable 3.1-4.1 MAF/Yr	Same	Same	Variable 3.1-4.2 MAF/Yr [e,j]	Same	Full Table A	Same	Revised SWP delivery logic. Three patterns with Art 56 and more accurately defined Table A / Article 21 split modeled
	SWP Demand - North Bay Aqueduct (Table A)	48 TAF/Yr	Same	Same	71 TAF/Yr[u]	Same	Same	Same	
	SWP Demand - Article 21 demand	Up to 134 TAF/month December to March, total of other demands up to 84 TAF/month in all months	Same	Same	Up to 314 TAF/month from December to March, total of demands up to 214 TAF/month in all other months[e,jw]	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Federal refuges	Firm Level 2	Same	Same	Recent Historical Firm Level 2 water needs[f]	Same	Firm Level 2 water needs[f]	Same	
FACILITIES									
Systemwide		Existing facilities[a]	Same	Same	Same	Same	Same	Same	
Sacramento Valley									
	Red Bluff Diversion Dam	No diversion constraint	Same	Same	Diversion Dam operated May 15 - Sept 15 (diversion constraint)	Same	Diversion Dam operated July - August (diversion constraint)	Same	
	Colusa Basin	Existing conveyance and storage facilities	Same	Same	Same	Same	Same	Same	
	Upper American River	No project	Same	Same	PCWA American River pump station[k]	Same	Same	Same	
	Sacramento River Water Reliability	No project	Same	Same	Same	Same	American/Sacramento River Diversions[t]	Same	
	Lower Sacramento River	No project	Same	Same	Same	Freeport Regional Water Project (Full Demand)[l]	Same	Same	
Delta Region									
	SWP Banks Pumping Plant	South Delta Improvements Program Temporary Barriers, 6,680 cfs capacity in all months and an additional 1/3 of Vernalis flow from Dec 15 through	Same	Same	Same	South Delta Improvements Program Permanent Operable Gates (Stage 1). 6,680 cfs capacity in all months and an additional 1/3 of Vernalis flow from Dec	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
		Mar 15[a]				15 through Mar 15 [a]			
	CVP C.W. Bill Jones (Tracy) Pumping Plant	4,200 cfs + deliveries upstream of DMC constriction	Same	Same	Same	4,600 cfs capacity in all months (allowed for by the Delta-Mendota Canal–California Aqueduct Intertie)	Same	Same	
	City of Stockton Delta Water Supply Project (DWSP)	No project	Same	Same	DWSP WTP 0 mgd	Same	DWSP WTP 30 mgd	Same	
	Contra Costa Water District	Existing pump locations	Same	Same	Same	Same	Same[m]	Same	
South of Delta **(CVP/SWP project facilities)**									
	South Bay Aqueduct (SBA)	Existing capacity 300 cfs	Same	Same	SBA Rehabilitation: 430 cfs capacity from junction with California Aqueduct to Alameda County FC&WSD Zone 7 diversion point	Same	Same	Same	
REGULATORY STANDARDS									
Trinity River									
	Minimum flow below Lewiston Dam	Trinity EIS Preferred Alternative (369-815	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
		TAF/year)							
	Trinity Reservoir end-of-September minimum storage	Trinity EIS Preferred Alternative (600 TAF as able)	Same	Same	Same	Same	Same	Same	
Clear Creek									
	Minimum flow below Whiskeytown Dam	Downstream water rights, 1963 USBR Proposal to USFWS and NPS, and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	Same	Same	Same	Same	
Upper Sacramento River									
	Shasta Lake	NMFS 2004 BiOp: 1.9 MAF end of Sep. storage target in non-critical years	Same	Same	Same	Same	Same	Same	
	Minimum flow below Keswick Dam	Flows for SWRCB WR 90-5 temperature control, and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	Same	Same	Same	Same	
Feather River									
	Minimum flow below Thermalito Diversion Dam	1983 DWR, DFG Agreement (600 cfs)	Same	Same	Same	2006 Settlement Agreement (700 / 800 cfs)	Same	Same	
	Minimum flow below Thermalito Afterbay outlet	1983 DWR, DFG Agreement (750-1,700 cfs)	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
Yuba River									
	Minimum flow below Daguerre Point Dam	Available Yuba River Data[p]	D-1644 Interim Operations[p]	Same	Yuba Accord Adjusted Data[p]	Same	Same	Same	
American River									
	Minimum flow below Nimbus Dam	SWRCB D-893 (see Operations Criteria), and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	(b)(2) Minimum Instream Flow management[s]	Same	American River Flow Management [s]	Same	
	Minimum Flow at H Street Bridge	SWRCB D-893	Same	Same	Same	Same	Same	Same	
Lower Sacramento River									
	Minimum flow near Rio Vista	SWRCB D-1641	Same	Same	Same	Same	Same	Same	
Mokelumne River									
	Minimum flow below Camanche Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (100-325 cfs)	Same	Same	Same	Same	Same	Same	
	Minimum flow below Woodbridge Diversion Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (25-300 cfs)	Same	Same	Same	Same	Same	Same	
Stanislaus River									
	Minimum flow below Goodwin Dam	1987 USBR, DFG agreement, and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Minimum dissolved oxygen	SWRCB D-1422	Same	Same	Same	Same	Same	Same	
Merced River	Minimum flow below Crocker-Huffman Diversion Dam	Davis-Grunsky (180-220 cfs, Nov-Mar), Cowell Agreement	Same	Same	Same	Same	Same	Same	
	Minimum flow at Shaffer Bridge	FERC 2179 (25-100 cfs)	Same	Same	Same	Same	Same	Same	
Tuolumne River	Minimum flow at Lagrange Bridge	FERC 2299-024, 1995 (Settlement Agreement) (94-301 TAF/year)	Same	Same	Same	Same	Same	Same	
San Joaquin River	Maximum salinity near Vernalis	SWRCB D-1641	Same	Same	Same	Same	Same	Same	
	Minimum flow near Vernalis	SWRCB D-1641, and Vernalis Adaptive Management Plan per San Joaquin River Agreement	Same	Same	Same	Same	Same	Same	
Sacramento River–San Joaquin River Delta	Delta Outflow Index (Flow and Salinity)	SWRCB D-1641	Same	Same	Same	Same	Same	Same	Revised Delta ANN (salinity estimation)[v]
	Delta Cross Channel gate operation	SWRCB D-1641	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Delta exports	SWRCB D-1641, USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	Same	Same	Same	Same	
OPERATIONS CRITERIA: RIVER-SPECIFIC									
Upper Sacramento River									
	Flow objective for navigation (Wilkins Slough)	3,250 - 5,000 cfs based on CVP water supply condition	Same	Same	Same	Same	Same	Same	
American River									
	Folsom Dam flood control	Variable 400/670 flood control diagram (without outlet modifications)	Same	Same	Same	Same	Same	Same	
	Flow below Nimbus Dam	Discretionary operations criteria corresponding to SWRCB D-893 required minimum flow	Same	Same	(b)(2) Minimum Instream Flow management[s]	Same	American River Flow Management [s]	Same	
	Sacramento Area Water Forum "Replacement" Water	"Replacement" water is not implemented	Same	Same	Same	Same	Same	Same	
Stanislaus River									
	Flow below Goodwin Dam	1997 New Melones Interim Operations Plan	Same	Same	Same	Draft Transitional Operations Plan[r]	Same	Same	
San Joaquin River									
	Flow at Vernalis	D1641	Same	Same	Same	Same	Same[q]	Same	

OPERATIONS CRITERIA: SYSTEMWIDE		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
CVP water allocation									
	CVP Settlement and Exchange	100% (75% in Shasta critical years)	Same	Same	Same	Same	Same	Same	
	CVP refuges	100% (75% in Shasta critical years)	Same	Same	Same	Same	Same	Same	
	CVP agriculture	100%-0% based on supply (South-of-Delta allocations are reduced due to D-1641 and 3406(b)(2) allocation-related export restrictions)	Same	Same	Same	Same	Same	Same	
	CVP municipal & industrial	100%-50% based on supply (South-of-Delta allocations are reduced due to D-1641 and 3406(b)(2) allocation-related export restrictions)	Same	Same	Same	Same	Same	Same	
SWP water allocation									
	North of Delta (FRSA)	Contract specific	Same	Same	Same	Same	Same	Same	
	South of Delta (including North Bay Aqueduct)	Based on supply; equal prioritization between Ag and M&I based on Monterey Agreement	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
CVP-SWP coordinated operations									
	Sharing of responsibility for in-basin-use	1986 Coordinated Operations Agreement (FRWP EBMUD and 2/3 of the North Bay Aqueduct diversions are considered as Delta Export, 1/3 of the North Bay Aqueduct diversion is considered as in-basin-use)	Same	Same	Same	Same	Same	Same	
	Sharing of surplus flows	1986 Coordinated Operations Agreement	Same	Same	Same	Same	Same	Same	
	Sharing of Export/Inflow Ratio	Equal sharing of export capacity under SWRCB D-1641; use of CVPIA 3406(b)(2) restricts only CVP and/or SWP exports	Same	Same	Same	Same	Same	Same	
	Sharing of export capacity for lesser priority and wheeling related pumping	Cross Valley Canal wheeling (max of 128 TAF/year), CALFED ROD defined Joint Point of Diversion (JPOD)	Same	Same	Same	Same	Same	Same	

		Study 3a	**Study 6.0 COMPARISON**	**Study 6.1 COMPARISON**	**Study 7.0 BASE MODEL**	**Study 7.1 ANALYTICAL**	**Study 8.0 ANALYTICAL**	**Study 9.0 - 9.5 SENSITIVITY**	**CalSim-II**
Study assumptions from above apply			**Study 6a**	**Study 7a**	**Study 7a**	**Study 7.1a**	**Study 8a**	**NA**	
CVPIA 3406(b)(2): Per May 2003 Dept. of Interior Decision									
	Allocation	800 TAF, 700 TAF in 40-30-30 dry years, and 600 TAF in 40-30-30 critical years[n]	Same	Same	Same	Same	Same	NA	
Study assumptions from above apply			**Study 6b**	**Study 7b**	**Study 7b**	**Study 7.1b**	**Study 8b**	**NA**	
CALFED Environmental Water Account / Limited Environmental Water Account									
	Actions	Dec-Feb reduce total exports by 50 TAF/mon relative to total exports without EWA; VAMP (Apr 15 - May 16) export restriction on SWP; Post (May 16-31) VAMP export restriction on SWP and potentially on CVP if B2 Post-VAMP action is not taken; Ramping of exports (Jun)	Dec/Jan 50 TAF/mon export reduction, Feb 50 TAF export reduction in Wet/AN years, Feb/Mar 100, 75, or 50 TAF reduction dependent on species habitat conditions; VAMP (Apr 15 - May 16) export restriction on SWP; Pre (Apr 1-14) VAMP export reduction in Dry/Crit years; Post (May 16-31) export restriction; June ramping restriction if PostVAMP action was done. Pre- and Post-VAMP and June actions done if foreseeable October debt at	NA	Same	VAMP (Apr 15 - May 16) 31-day export restriction on SWP; If stored assets and purchases from the Yuba are sufficient, Post (May 16-31) VAMP export restrictions apply to SWP[pq]	Same	NA	The EWA actions, assets, and debt were revised and vetted as part of the Long Term Environmental Water Account EIS/R project

	Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
		San Luis does not exceed 150 TAF.						
Assets	Fixed Water Purchases 250 TAF/yr, 230 TAF/yr in 40-30-30 dry years, 210 TAF/yr in 40-30-30 critical years. The purchases range from 0 TAF in Wet years to approximately 153 TAF in Critical years NOD, and 57 TAF in Critical years to 250 TAF in Wet years SOD. Variable assets include the following: use of 50% of any CVPIA 3406(b)(2) releases pumped by SWP, flexing of Delta E/I Ratio (post-processed from CalSim-II results), additional 500 CFS pumping capacity at Banks in Jul-Sep	Fixed Water Purchases 250 TAF/yr, 230 TAF/yr in 40-30-30 dry years, 210 TAF/yr in 40-30-30 critical years. NOD share of annual purchase target ranges from 90% to 50% based on SWP Ag Allocation as an indicator of conveyance capacity. Variable/operational assets include use of 50% of any CVPIA 3406(b)(2) releases pumped by SWP, additional 500 CFS pumping capacity at Banks in Jul-Sep, source shifting, Semitropic Groundwater Bank, “spill” of San Luis carryover debt, and backed-up stored water from Spring EWA actions.	NA	Same	Purchase of Yuba River stored water under the Lower Yuba River Accord (average of 48 TAF/yr), use of 50% of any CVPIA 3406 (b)(2) releases pumped by SWP, additional 500 CFS pumping capactiy at Banks in Jul-Sep.	Same	NA	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Debt	Delivery debt paid back in full upon assessment; Storage debt paid back over time based on asset/action priorities; SOD and NOD debt carryover is explicitly managed or spilled; NOD debt carryover must be spilled; SOD and NOD asset carryover is allowed	Same	NA	Same	No Carryover Debt	Same	NA	
Post Processing Assumptions									
WATER MANAGEMENT ACTIONS (CALFED)									
Water Transfers									
	Water transfers	Acquisitions by SWP contractors are wheeled at priority in Banks Pumping Plant over non-SWP users	Same	NA	Same	Same	Same	NA	
	Phase 8[o]	Evaluate available capacity	Same	NA	Same	Same	Same		
	Refuge Level 4 water	Evaluate available capacity	Same	NA	Same	Same	Same		

	Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II

Notes:

[a] The OCAP BA project description is presented in Chapter 2.

[b] Climate change sensitivity analysis assumptions and documentation are presented in Appendix R.

[c] The Sacramento Valley hydrology used in the CALSIM II model reflects 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation. Development of 2030 land-use assumptions are being coordinated with the California Water Plan Update for future models.

[d] CVP contract amounts have been reviewed and updated according to existing and amended contracts as appropriate. Assumptions regarding CVP agricultural and M&I service contracts and Settlement Contract amounts are documented in Table 3A (North of Delta) and 5A (South of Delta) of Appendix D: Delivery Specifications section of the Technical Appendix.

[e] SWP contract amounts have been reviewed and updated as appropriate. Assumptions regarding SWP agricultural and M&I contract amounts are documented in Table 1A (North of Delta) and Table 2A (South of Delta) of Appendix D: Delivery Specifications section.

[f] Water needs for federal refuges have been reviewed and updated as appropriate. Assumptions regarding firm Level 2 refuge water needs are documented in Table 3A (North of Delta) and 5A (South of Delta) of Appendix D:Delivery Specifications. Incremental Level 4 refuge water needs have been documented as part of the assumptions of future water transfers.

[g] PCWA demand in the foreseeable existing condition is 8.5 TAF/yr of CVP contract supply diverted at the new American River PCWA Pump Station. In the future scenario, PCWA is allowed 35 TAF/yr. Assumptions regarding American River water rights and CVP contracts are documented in Table 5 of Appendix D: Delivery Specifications section.

[h] The new CalSim-II representation of the San Joaquin River has been included in this model package (CalSim-II San Joaquin River Model, Reclamation, 2005). Updates to the San Joaquin River have been included since the preliminary model release in August 2005. The model reflects the difficulties of on-going groundwater overdraft problems. The 2030 level of development representation of the San Joaquin River Basin does not make any attempt to offer solutions to on-going groundwater overdraft problems. In addition, a dynamic groundwater simulation is not yet developed for San Joaquin River Valley. Groundwater extraction/ recharge and stream-groundwater interaction are static assumptions and may not accurately reflect a response to simulated actions. These limitations should be considered in the analysis of results.

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II

[i] Study 6.0 demands for CCWD are assumed equal to Study 7.0 due to data availablity with the revised CalSim-II model framework. For all Studies, Los Vaqueros Reservoir storage capacity is 100 TAF.

[j] Table A deliveries into the San Francisco Bay Area Region for existing cases are based on a variable demand and a full Table A for future cases. The variable demand is dependent on the availability of other water during wet years resulting in less demand for Table A. In the future cases it is assumed that the demand for full Table A will be independent of other water sources. Article 21 demand assumes MWD demand of 100 TAF/mon (Dec-Mar), Kern demand of 180 TAF/mon (Jan-Dec), and other contractor demand of 34 TAF/mon (Jan-Dec).

[k] PCWA American River pumping facility upstream of Folsom Lake is under construction.

[l] Mokelumne River flows reflect EBMUD supplies associated with the Freeport Regional Water Project.

[m] The CCWD Alternate Intake Project (AIP), an intake at Victoria Canal, which operates as an alternate Delta diversion for Los Vaqueros Reservoir is not included in Study 8.0. AIP is included as a separate consultation. AIP will be further evaluated after regulatory and operational managment assumptions have been determined.

[n] The allocation representation in CalSim-II replicates key processes, shortage changes are checked by post-processing.

[o] This Phase 8 requirement is assumed to be met through Sacramento Valley Water Management Agreement Implementation.

[p] OCAP BA 2004 modeling used available hydrology at the time which was data developed based on 1965 Yuba County Water Agency -Department of Fish of Game Agreement. Since the OCAP BA 2004 modeling, Yuba River hydrology was revised. Interim D-1644 is assumed to be fully implemented with or without the implementation of the Lower Yuba River Accord. This is consistent with the future no-action condition being assumed by the Lower Yuba River Accord EIS/EIR study team. For studies with the Lower Yuba River Accord, an adjusted hydrology is used.

[q] It is assumed that either VAMP, a functional equivalent, or D-1641 requirements would be in place in 2030.

[r] The Draft Transitional Operations Plan assumptions are discussed in Chapter 2.

[s] For Studies 7.0, 7.1, and 8.0 the flow components of the proposed American River Flow Management are included and applied using the CVPIA 3406(b)(2). For Study 8.0 the American River Flow Management is assumed to be the new minimum instream flow.

[t] OCAP assumes the flexibility of diversion location but does not assume the Sacramento Area Water Forum Water Forum "replacement water" in drier water year types.

[u] Aqueduct improvements that would allow an increase in South Bay Aqueduct demand at the time of model development were expected to be operational within 6 months. However, a delay in the construction has postponed the completion.

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II

[v] The Artificial Neural Network (ANN) was updated for both salinity and X2 calculations. Study 3a does not include an updated ANN, Study 6.1 has an updated salinity but not X2, and all remaining Studies include both the updated salinity and X2.

[w] North Bay Article 21 deliveries are dependent on excess conditions rather than being dependent on San Luis storage.

Assumed Future Demands

The CalSim-II model results are very sensitive to assumed demands for the CVP and SWP systems. The modeled representation of future demands are assumed as full water right and contract demands for the CVP and full Table A for the SWP. Assumed delivery specifications for diversion locations in the CalSim-II model are listed in detail for both the existing and future levels of development in the Appendix D.

The following explains only the significant future delivery assumptions that deviate from the previous OCAP BA model representation (OCAP BA, 2004):

- The future total American River Basin water demand is greater than the demands assumed for 2004 BA analysis and, does not include the representation of the Water Forum program for demand reductions in certain dry and critical hydrologic conditions. The modeling assumes 311,800 af/yr in future water right demands for the city of Sacramento which is also greater than the previous models (the OCAP BA 2004 simulated a year 2020 level of development, the current OCAP BA simulates a year 2030 level of development). Finally, the modeling does not include the representation of the Water Forum program for additional releases from the Middle Fork Project. These changes represent a more realistic picture of the CVP's ability to meet water rights and water contract obligations. Another important change is the representation of the American River minimum flow requirements below Lake Natoma. These flows are augmented according to the proposed American River Flow Management schedule.
- The Sacramento River Reliability Project also affects the future representation which reduces the delivery burden on the American River by shifting demands to a Sacramento River diversion. Assumed delivery specifications for the American River are also listed in the CalSim-II modeling Appendix D.
- The City of Stockton Delta Water Supply Project is included in the future representation. This captures the expansion of future Delta demands with the development of the 30 mgd Delta Water Supply Project.
- The modeling of SWP deliveries has been significantly refined in the latest version of CalSim-II to better reflect current delivery classification practices. The three significant changes in the delivery modeling are 1) the incorporation of a three-pattern demand, 2) explicit modeling of the previous year's Table A supplies that are delivered in the current year ("Carryover" or Article 56 deliveries), and 3) increased assumption for Article 21 demands.
  - The three-pattern demand allows for demand adjustments associated with various levels of Table A allocation. Based on the amount of Table A allocation one of the three demand patterns is selected to more accurately model the monthly delivery pattern.
  - In the model used for the 2004 BA, a single demand pattern was used with the current year's Article 56 water inappropriately delivered at the beginning of the current year rather than being carried over for delivery in the following year. This artificially increased the Table A demand at the beginning of each year, and

potentially reduced Article 21 deliveries during the early part of the year. The new delivery methodology allows for the storage, delivery and “spilling” of the previous year’s Article 56 carryover at the beginning of the current year. Delivery of the previous year’s Article 56 is typically within the first three months of the current year. As the SWP share of San Luis Reservoir fills, there is a chance that Article 56 will “spill” i.e. it is converted to the current year’s Table A supply.

- The new model also incorporates an Article 21 demand increase that more accurately represents actual Article 21 demand. However, with the incorporation of the three-pattern Table A demand, Article 56, and increased Article 21 demand, the overall total delivery remains largely the same. The previous version of the model tended to overestimate the delivery of Table A and underestimate the delivery of Article 21 by a like amount.
- The existing condition studies (Study 7.0, and Study 7.1) used a variable annual Table A demand which is consistent with the 2004 modeling. This assumes that the demand for Table A water would be less during very wet years, but would be greater in dry years.
- The future condition studies (Study 8.0, and Studies 9 suite) used full entitlement demand in all years. This condition assumes that, independent on the year type, the demand would remain the same. By contrast, the 2004 modeling assumed a variable demand for the future condition studies.

Modeling Results

Hydrologic Modeling Results

A summary of long-term averages (i.e., WY1922 to WY2003) and critical drought-period averages (i.e., WY1928 to WY1934) is shown in Table 9-6 for flows, storages, Delta output, and deliveries. These values represent long-term averages, for example CalSim-II results for CVP SOD Agricultural allocations range from 0 to 100 percent. The remaining section presents results for 3406 CVPIA (b)(2) accounting and EWA. Discussions of results are presented in Chapter 10: Streams Controlled by CVP and SWP Operations and Chapter 12: CVP and SWP Delta Operations. Additional results, including month-by-year tables, exceedance charts, monthly averages by water-year type, and monthly percentiles for selected CalSim-II outputs, are located in the appendix (Appendix E).

Selected results in this chapter are shown in exceedance charts for a particular month or set of months, average and percentile monthly data, and sorted by water-year type for a particular month. The probability-of-exceedance charts show values on the y-axis with the percent of time (probability of exceedance) that the value was exceeded. For example, the end-of-September exceedance charts show the probability that the reservoir was able to carry over storage into the next water year for each of the studies. The exceedance charts are also a good measure of trend between the studies, either higher or lower on average. Averages by water-year type are sorted in this chapter based on the 40-30-30 Sacramento Valley Index and show how the average changes from Wet to Critical years. The 60-20-20 San Joaquin Valley Index was used for sorting temperature and CalSim-II output from the Stanislaus and San Joaquin rivers. The percentile graphs show monthly values for the 50th, 5th, and 95th percentiles for a given output variable and were used to indicate how flows are being affected by flood and minimum-flow requirements.

Table 9-6. Long-term Averages and 28-34 Averages From Each of the Five Studies

	Study 3a Today EWA 2004 OCAP BA		Study 6.0 Today EWA: Revised Model/Study 3a Assumptions		Study 7.0 Today EWA		Study 7.1 Near Future Limited EWA		Study 8.0 Future Limited EWA	
End of Sep Storages (TAF)	1922-94	1929-34	1922-2003	1929-34	1922-2003	1929-34	1922-2003	1929-34	1922-2003	1929-34
Trinity	1302	579	1417	718	1424	697	1417	697	1422	735
Whiskeytown	232	213	235	235	234	226	234	226	234	227
Shasta	2590	1176	2867	1682	2893	1659	2772	1400	2772	1558
Folsom	533	387	546	409	560	400	542	381	522	382
New Melones	1380	832	1470	864	1488	887	1497	882	1556	1043
CVP San Luis	243	388	180	133	180	146	218	198	211	289
SWP San Luis	339	359	390	428	444	397	501	359	417	328
Total San Luis	596	893	585	571	633	555	742	572	646	631
Trinity-Shasta-Folsom	4424	2142	4831	2810	4877	2756	4732	2478	4716	2675
River Flows (cfs)										
Trinity Release	925	566	970	566	970	566	972	566	970	566
Clear Creek Tunnel	747	503	738	467	737	516	736	488	737	469
Clear Creek Release	165	95	173	120	168	106	168	103	171	117
Keswick Release	8355	5544	8558	5421	8560	5502	8570	5478	8568	5375
Nimbus Release	3456	1940	3493	1886	3482	1904	3482	1867	3319	1751
Mouth of American	3325	1803	3323	1719	3355	1782	3356	1746	2945	1375
Sac River blw Red Bluff Diversion Dam	10929	6973	11282	6814	11276	6883	11290	6870	11322	6843
Wilkin's Slough	8924	5505	9409	5694	9378	5785	9213	5544	9187	5472
Sac at Freeport	22108	11571	22690	11745	22614	11943	22375	11490	22355	11379
Goodwin Release	600	301	629	156	654	352	662	415	654	366
Stanislaus Mouth	886	488	763	196	790	408	798	471	790	422
SJR Flow w/o Stanislaus	2844	1235	3341	950	3383	1457	3378	1449	3335	1418
Flow at Vernalis	3694	1685	4192	1885	4209	1888	4212	1943	4161	1862
Yolo Bypass	2016	167	2742	129	2720	131	2685	148	2657	158
Mokelumne	869	278	924	281	924	281	918	286	918	286
Spring Creek Tunnel	926	518	934	444	938	506	937	481	935	449

	Study 3a Today EWA 2004 OCAP BA		Study 6.0 Today EWA: Revised Model/Study 3a Assumptions		Study 7.0 Today EWA		Study 7.1 Near Future Limited EWA		Study 8.0 Future Limited EWA	
Delta Parameters										
SWP Banks (cfs)	4172	2368	4393	2468	4453	2662	4601	2760	4646	2679
CVP Banks (cfs)	172	39	131	54	108	42	116	35	110	22
Jones (cfs)	3157	2010	3209	2171	3205	2214	3335	2302	3305	2149
Total Banks (cfs)	4487	2671	4748	2829	4803	3056	4808	2864	4849	2768
Cross Valley Pumping (cfs)	105	20	104	40	93	41	96	35	93	22
Sac Flow at Freeport (cfs)	22108	11571	22690	11745	22614	11943	22375	11490	22355	11379
Flow at Rio Vista (cfs)	18127	7254	19394	7361	19238	7460	19011	7139	18956	7079
Excess Outflow (cfs)	11969	1380	15608	1729	15366	1599	14907	1262	14742	1312
Required Outflow (cfs)	7766	6014	5691	5631	5728	5632	5778	5699	5800	5693
X2 Position (km)	76	82	76	85	76	85	76	85	76	85
Yolo Bypass (cfs)	2016	167	2742	129	2720	131	2685	148	2657	158
Mokelumne Flow (cfs)	869	278	924	281	924	281	918	286	918	286
SJR + Calaveras Flow (cfs)	3887	1755	4351	1911	4354	1899	4356	1955	4308	1876
Modeled Required DO (cfs)	7506	5669	5698	5648	5734	5656	5778	5699	5800	5693
Flow at Georgiana Slough (cfs)	3769	2368	3847	2391	3837	2417	3805	2357	3802	2342
DXC Flow (cfs)	1749	1594	1738	1607	1746	1637	1734	1582	1739	1562
Flow below DXC (cfs)	16590	7609	17106	7747	17031	7889	16836	7551	16814	7474
North Bay Aqueduct (cfs)	54	27	64	47	123	91	120	91	134	92
CCWD (cfs)	171	159	175	185	174	186	174	185	224	234
Total Outflow (cfs)	19735	7394	21300	7359	21094	7231	20685	6961	20542	7005
Total Inflow (cfs)	28881	13772	30707	14067	30612	14255	30335	13878	30239	13698
Old&Middle River (cfs)	--	--	-4833	-3471	-4870	-3717	-4992	-3589	-5031	-3410
QWEST (cfs)	--	--	1892	12	1784	-260	1604	-209	1501	-107
Deliveries (TAF)										
CVP										
North of Delta										
Agriculture	228	32	251	83	254	85	249	73	241	45
Settlement Contracts	1832	1750	1661	1564	1672	1543	1838	1727	1857	1735
M&I	26	27	46	40	80	62	80	62	219	155

	Study 3a Today EWA 2004 OCAP BA		Study 6.0 Today EWA: Revised Model/Study 3a Assumptions		Study 7.0 Today EWA		Study 7.1 Near Future Limited EWA		Study 8.0 Future Limited EWA	
Refuge	101	91	72	62	71	62	72	62	90	78
Total	2199	1899	2029	1748	2077	1753	2239	1923	2407	2013
South of Delta										
Agriculture	1074	161	1104	420	1078	428	1092	354	1089	232
Exchange	841	737	852	741	852	741	852	741	852	741
M&I	119	84	124	98	123	100	127	98	127	92
Refuge	274	240	294	246	295	252	296	253	273	234
Total**	2503	1406	2558	1689	2533	1702	2550	1624	2525	1483
SWP										
Allocation	2798	1449	3343	1583	3369	1539	3276	1571	3251	1526
Table A	2798	1449	2967	1508	2565	1394	2513	1457	2996	1455
Article 56	0	0	0	0	342	136	340	107	113	38
Article 21	162	173	291	200	444	384	470	347	285	348
Table A + Art 56	2798	1449	2967	1508	2907	1531	2853	1564	3109	1493
Table A + Art 56 + Art 21	2960	1622	3258	1708	3350	1915	3323	1911	3394	1841
Anticipated Carryover	0	0	0	0	485	71	458	40	181	4
Allocations (%)										
CVP Allocation										
North of Delta										
Agriculture	69%	18%	74%	31%	75%	34%	73%	29%	69%	21%
M&I	87%	64%	91%	74%	91%	74%	90%	73%	89%	67%
South of Delta										
Agriculture	60%	18%	61%	31%	61%	33%	60%	29%	60%	21%
M&I	86%	64%	87%	74%	87%	74%	87%	73%	87%	67%
SWP										
All SWC	68%	35%	79%	38%	80%	36%	77%	37%	77%	36%

CVPIA 3406 (b)(2)

This section analyzes water use for the CVPIA Section 3046 (b)(2), known as "(b)(2)" actions. Results from the CalSim-II accounting describe the long-term average (b)(2) costs for each study by water year type (see Table 9-8, Table 9-9, and Table 9-10). The long-term average annual cost of (b)(2) water use ranges from 671 taf annually to 689 taf annually.

Simulated (b)(2) costs for individual years (1922 – 2003) are presented in Figure 9-8, Figure 9-9,

Figure 9-10, and

Figure 9-10. These plots show the Water Quality Control Plan (WQCP) costs (non-discretionary) that are accounted up to 500 taf per year and discretionary or (b)(2) costs. The (b)(2) allocation, based on hydrologic conditions, are also noted for each year. CalSim-II does not use any forecasting algorithm for overall (b)(2) costs. This also results in over- and under-utilization of the allocated amount of (b)(2) water. The years when the (b)(2) costs are less than the allocated amount are generally Wet years, because flood releases are nearly identical between the D-1485 baseline and (b)(2) annual simulations, and VAMP export curtailments are up to the 2:1 ratio when non-VAMP flows are greater than 8,600 cfs.

An additional measure of (b)(2) performance is the probability of exceeding the 200 taf target during the October–January period. The probability of exceeding 200 taf October – January for Study 6.0, Study 7.0, Study 7.1, and Study 8.0 is 20%, 17%, 15%, and 25% respectively (Figure 9-13, Figure 9-14, and Figure 9-13). Exceeding the 200-taf target is generally a result of the model taking high-cost upstream actions (at Nimbus and Keswick) before the accounting algorithms can reduce costs for this period. Another reason for high costs during this period is Delta salinity requirements during Dry and Critical years in the WQCP accounting. Similar percent exceedence graphics are presented for the total annual WQCP and (b)(2) costs in Figure 9-17, Figure 9-18, and Figure 9-16.

Table 9-11 shows the average required costs for a (b)(2) export action and what the simulated (b)(2) operation was able to support with the water available in the account and anticipated WQCP costs for Studies 6.0, 7.0, 7.1, and 8.0. Study 8.0 shows a shift in actions where June Ramping and May Shoulders slightly increased and April-May VAMP slightly decreased. However, the frequency of (b)(2) releases and export reductions are similar between Studies 6.0, 7.0, 7.1, and 8.0. This is presented in Table 9-12 which lists the percentage of times that the simulated actions were triggered under the assumptions for taking an action.

Table 9-7 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 6.0 Today

Study 6.0	Oct	Nov	Dec	Jan	Oct-Jan Sub total	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
WQCP Release Cost	5	8	8	1	22	20	14	5	8	64	11	30	35	208
WQCP Export Cost	4	3	8	2	17	13	25	44	19	3	23	68	2	214
WQCP Total Cost	9	10	16	3	39	33	40	48	27	67	33	97	37	421
(b)(2) Release Cost	20	38	48	30	136	28	40	38	29	49	13	22	19	375
(b)(2) Export Cost	4	1	1	2	7	14	27	79	61	11	29	72	6	306
(b)(2) Total Cost	23	39	49	32	143	42	68	117	90	61	43	94	25	682

Table 9-8 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 7.0 Today

Study 7.0	Oct	Nov	Dec	Jan	Oct-Jan Subtotal	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
WQCP Release Cost	14	19	30	15	79	14	9	7	16	60	10	28	41	264
WQCP Export Cost	1	2	6	5	13	17	27	46	18	3	41	81	3	249
WQCP Total Cost	15	21	36	20	93	31	35	53	35	63	50	109	45	513
(b)(2) Release Cost	16	35	49	32	133	18	25	36	33	51	12	28	26	361
(b)(2) Export Cost	2	1	6	3	13	15	28	77	62	9	43	85	6	338
(b)(2) Total Cost	18	36	55	36	145	33	53	113	95	60	55	112	32	699

Table 9-9 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 7.1 Near Future

Study 7.1	Oct	Nov	Dec	Jan	Oct-Jan Subtotal	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
WQCP Release Cost	13	24	26	19	82	19	8	7	13	62	7	29	32	260
WQCP Export Cost	2	2	9	5	18	21	32	42	16	5	26	68	2	229
WQCP Total Cost	16	26	35	24	101	40	40	49	30	66	33	97	34	489
(b)(2) Release Cost	15	33	44	29	120	24	25	20	18	48	8	28	20	312
(b)(2) Export Cost	2	1	8	5	16	23	41	70	65	11	32	70	5	332
(b)(2) Total Cost	17	33	52	34	136	47	66	90	83	59	40	98	25	643

Table 9-10 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 8.0 Future

Study 8.0	Oct	Nov	Dec	Jan	Oct-Jan Subtotal	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
WQCP Release Cost	12	26	27	21	87	16	11	4	14	59	10	20	35	256
WQCP Export Cost	2	1	7	5	15	21	28	40	20	8	22	67	2	224
WQCP Total Cost	14	28	34	26	103	38	38	44	34	66	32	88	38	480
(b)(2) Release Cost	15	37	44	31	127	26	28	20	19	50	10	23	20	322
(b)(2) Export Cost	3	1	7	4	15	18	37	64	68	13	28	70	5	318
(b)(2) Total Cost	18	38	51	36	142	43	65	84	86	63	38	93	25	640

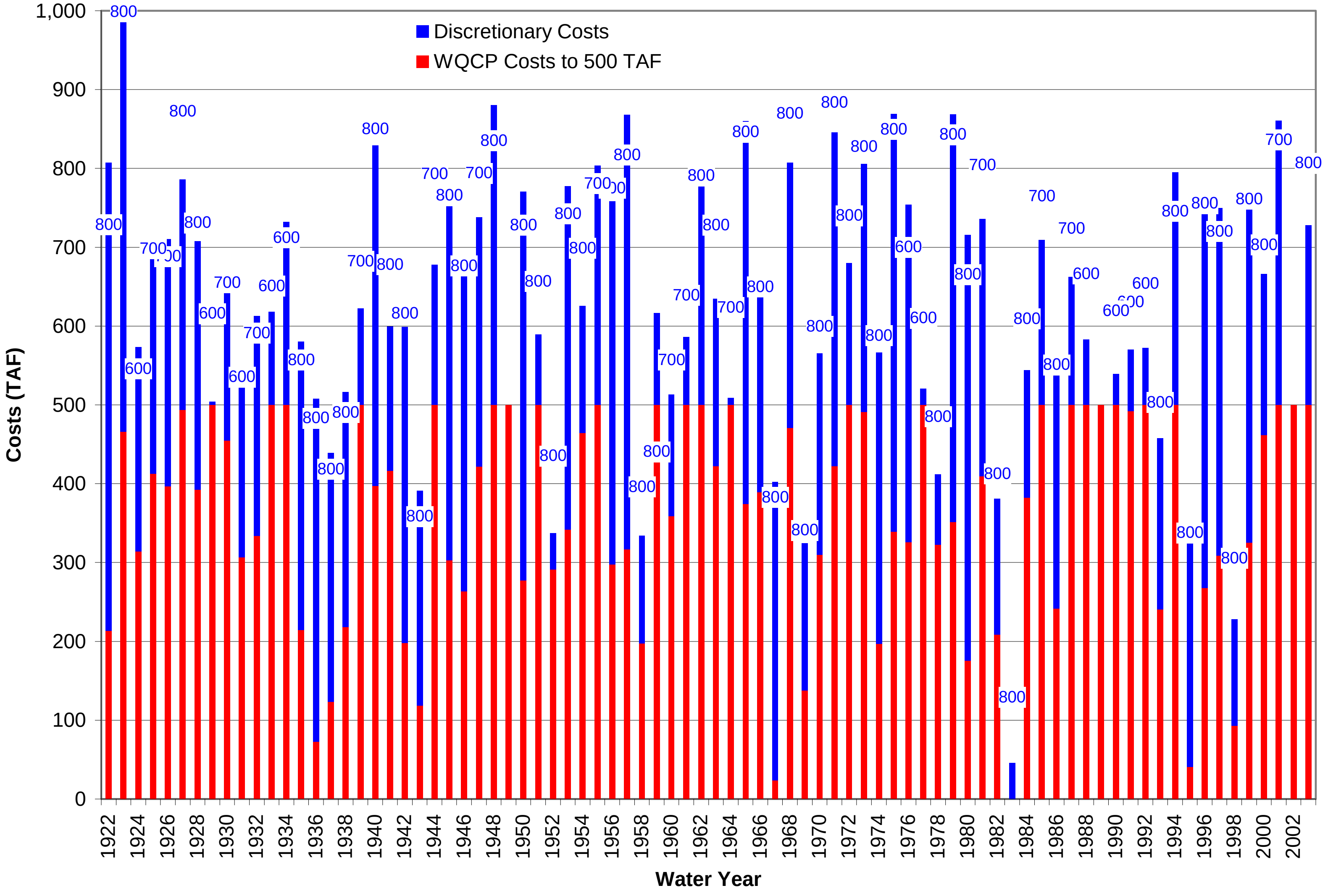

Figure 9-7 Study 6.0 Total Annual WQCP and Total (b)(2) Costs

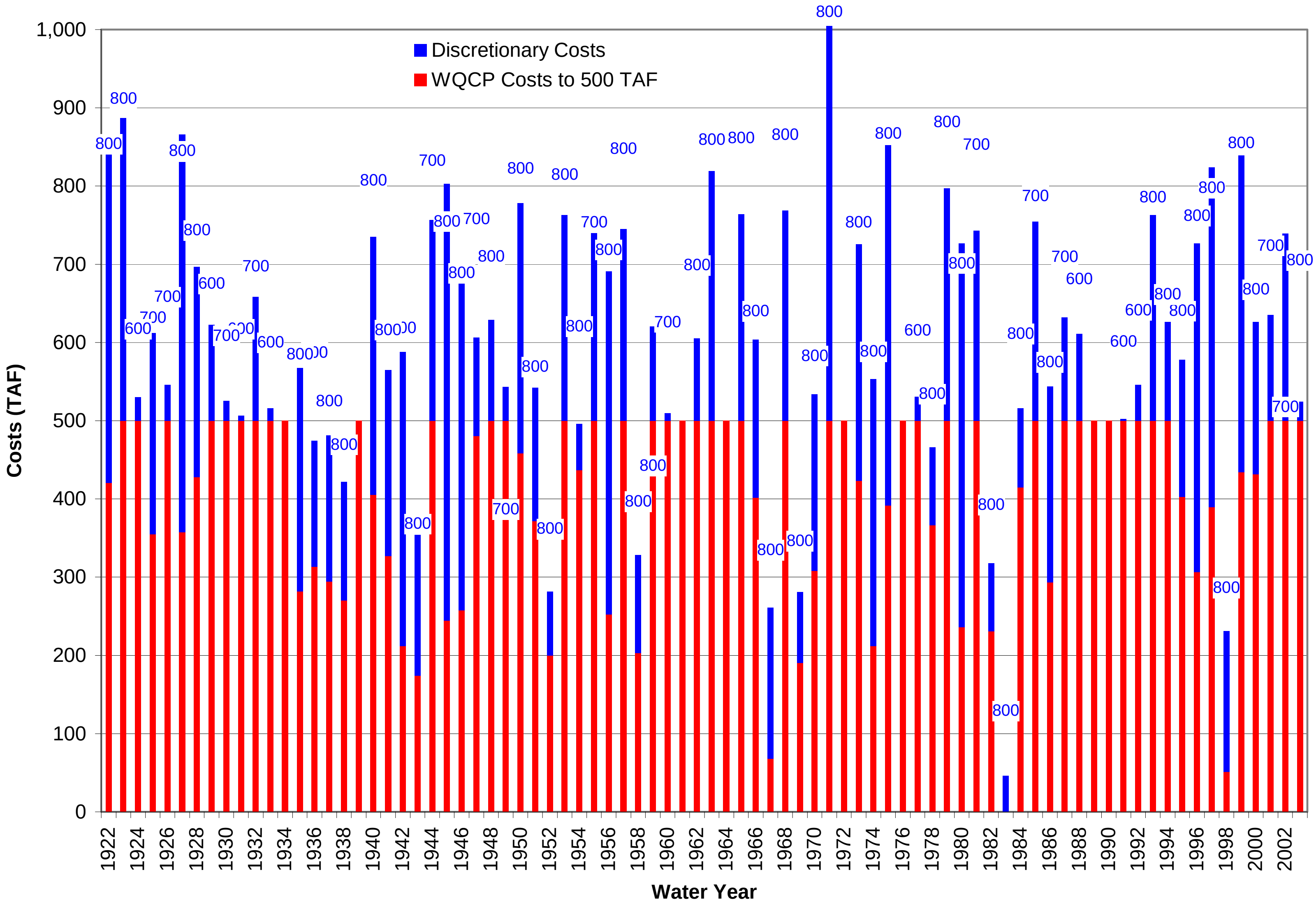

Figure 9-8 Study 7.0 Total Annual WQCP and Total (b)(2) Costs

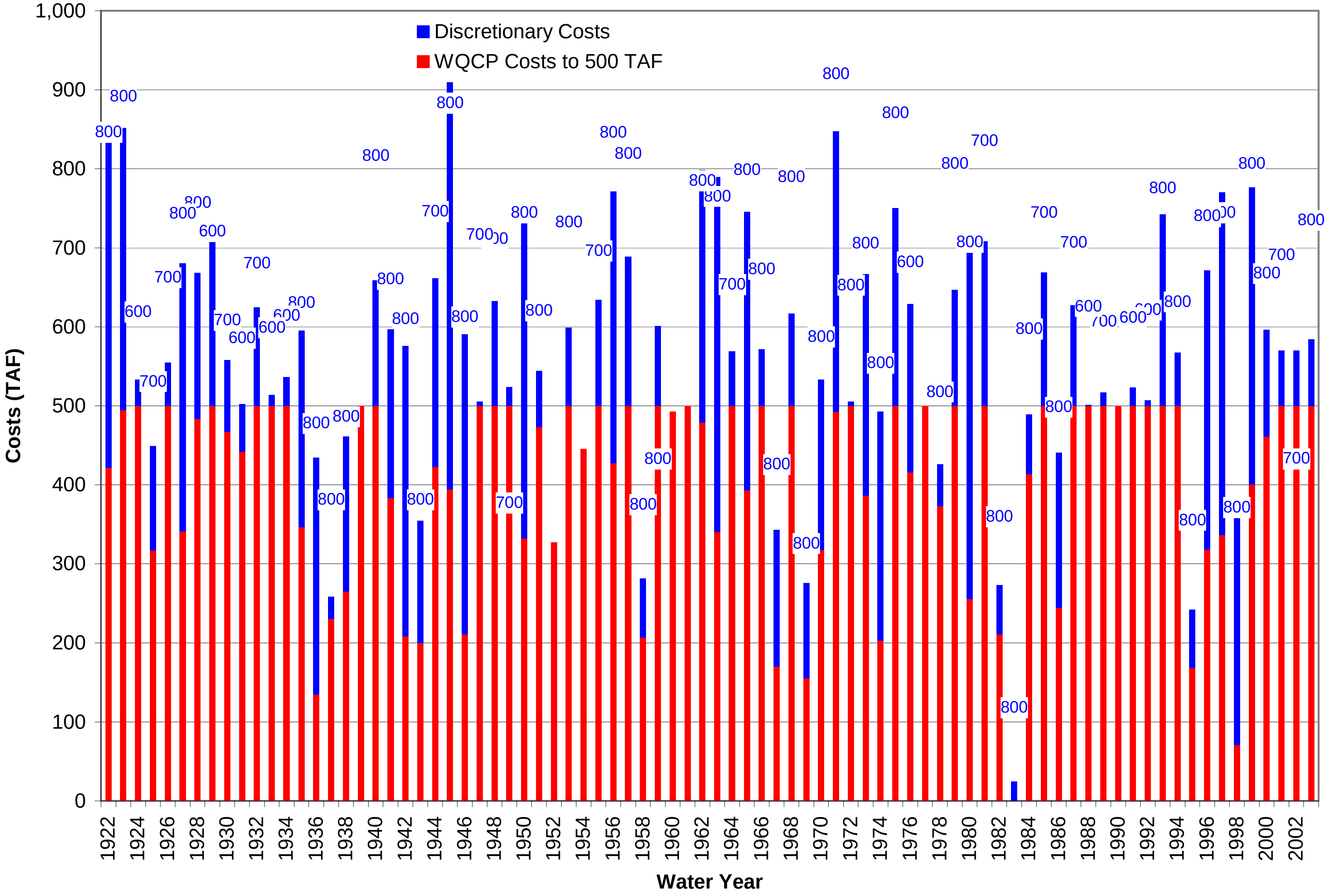

Figure 9-9 Study 7.1 Total Annual WQCP and Total (b)(2) Costs

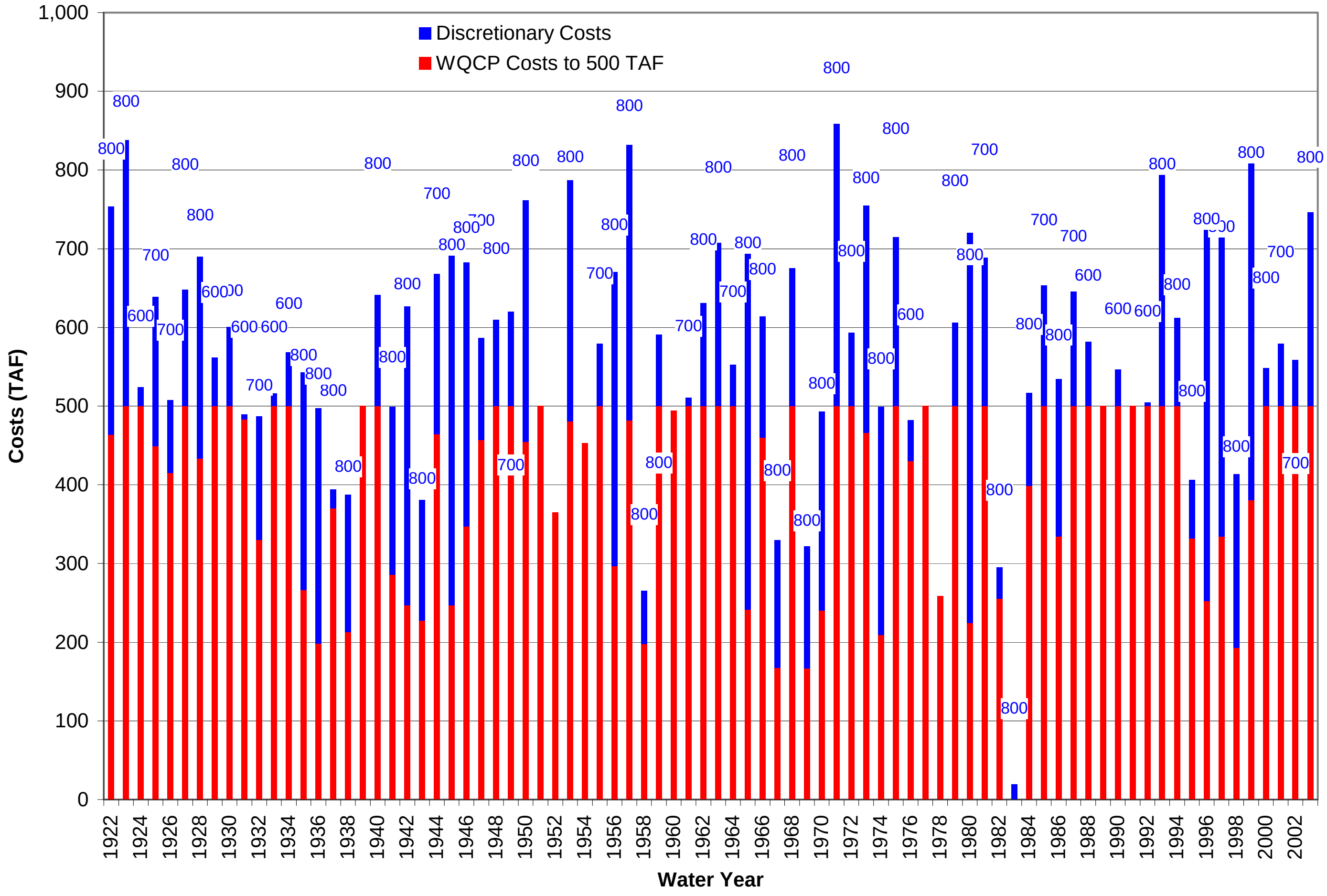

Figure 9-10 Study 8.0 Total Annual WQCP and Total (b)(2) Costs

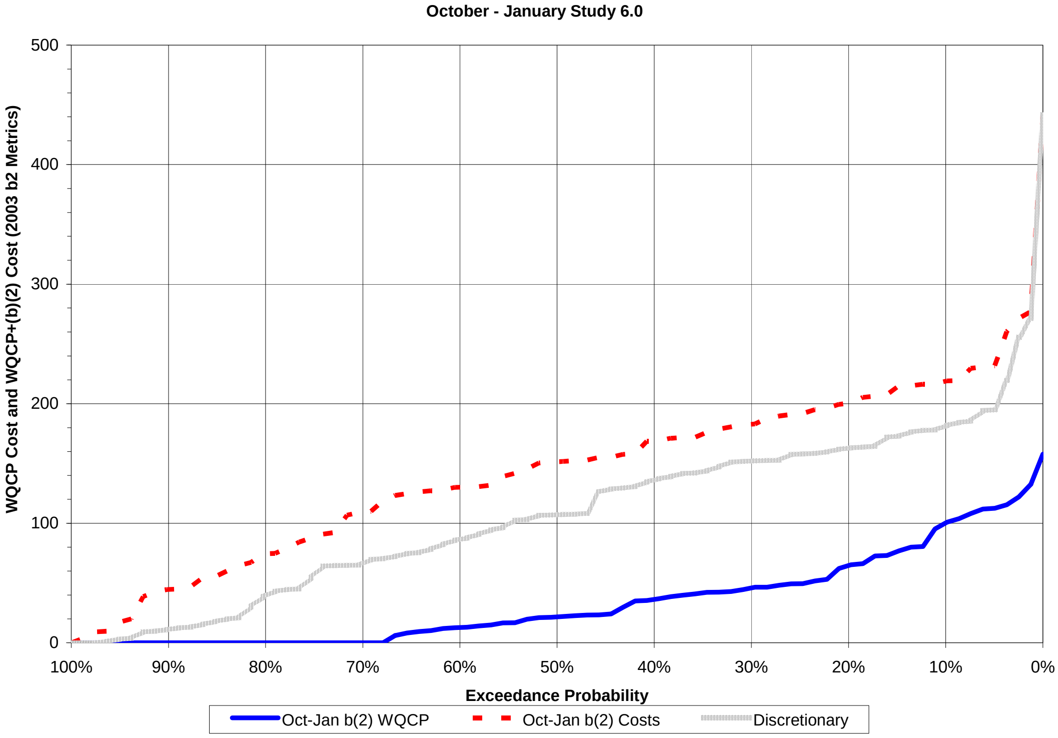

Figure 9-11 Oct – Jan WQCP and Total (b)(2) Costs Probability of Exceedance Study 6.0

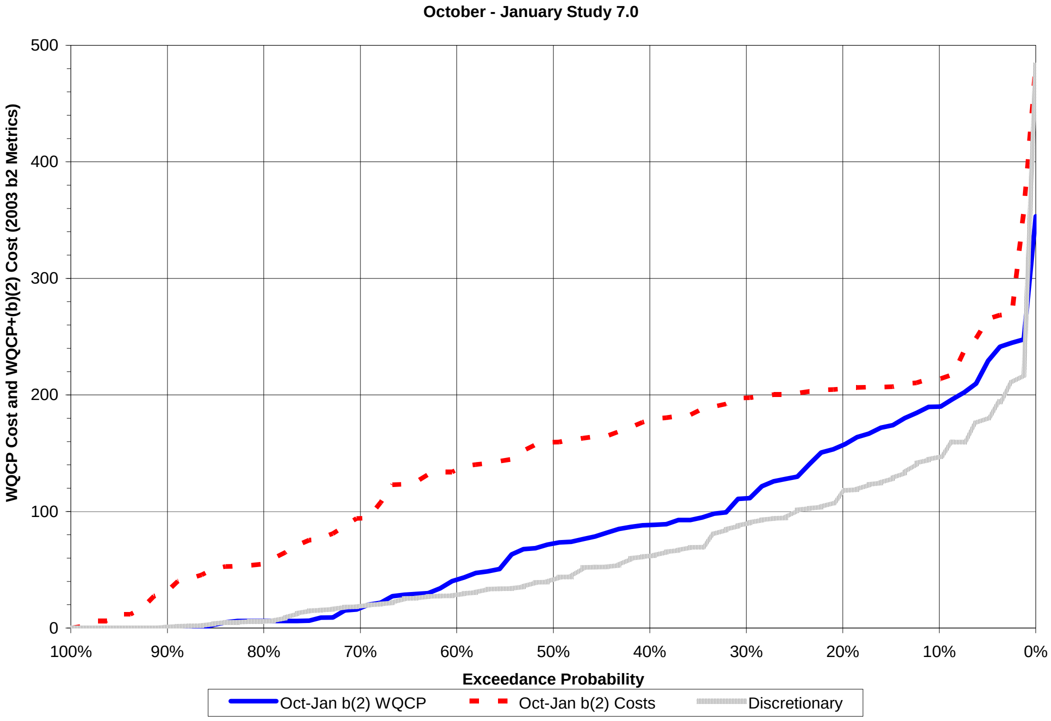

Figure 9-12 Oct – Jan WQCP and Total (b)(2) Costs Probability of Exceedance Study 7.0

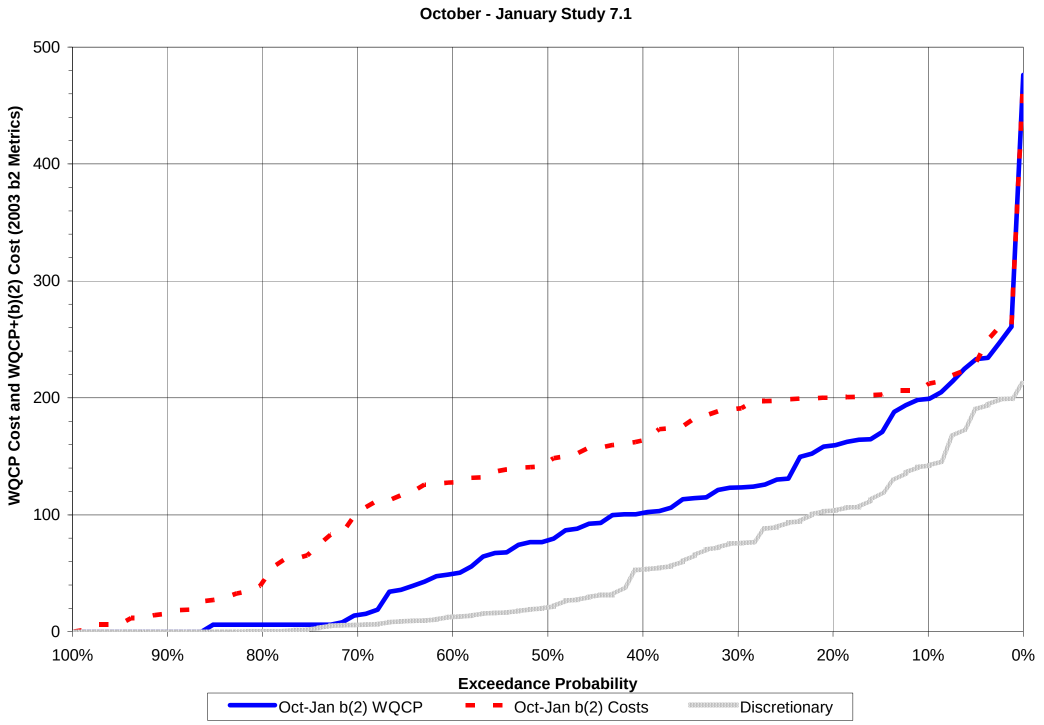

Figure 9-13 Oct – Jan WQCP and Total (b)(2) Costs Probability of Exceedance Study 7.1

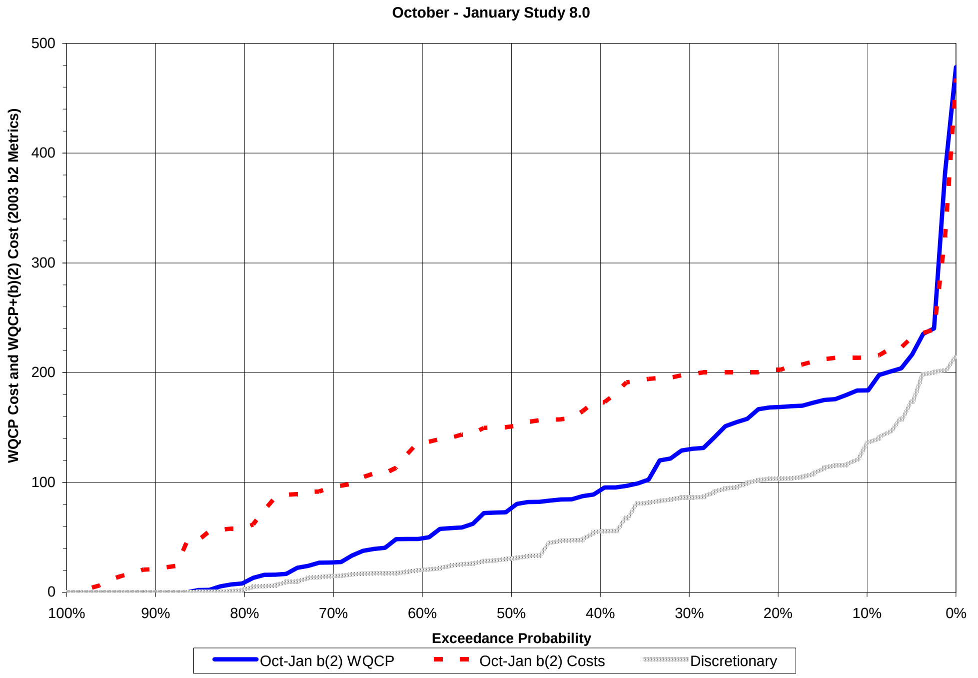

Figure 9-14. Oct – Jan WQCP and Total (b)(2) Costs Probability of Exceedance Study 8.0

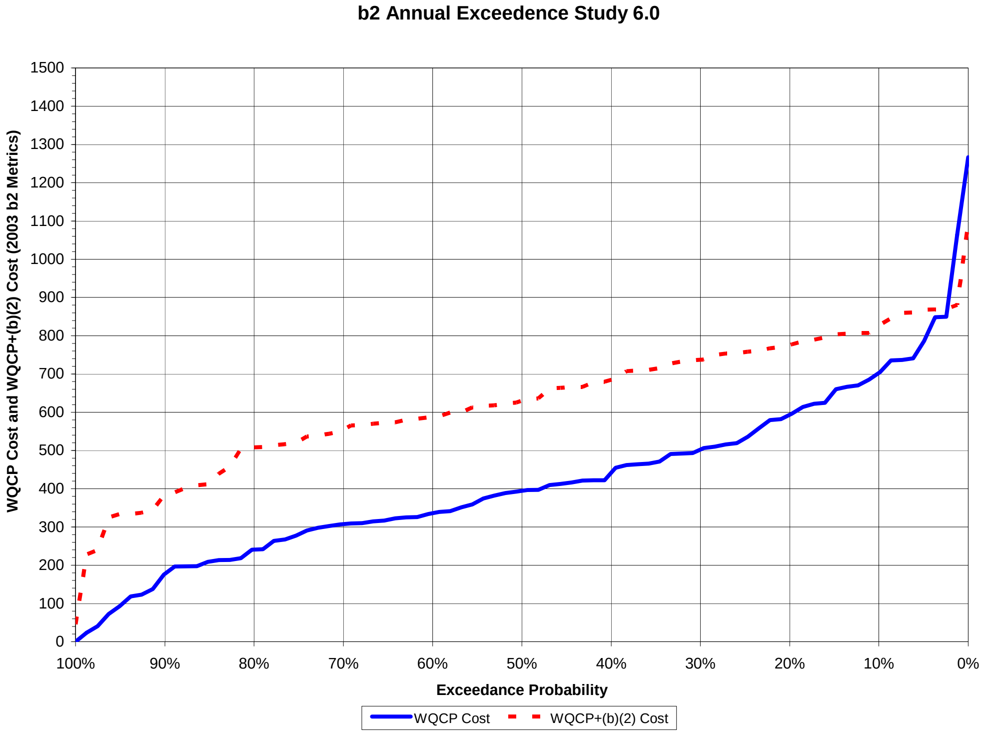

Figure 9-15 Annual WQCP and Total (b)(2) Costs Probability of Exceedance for Study 6.0

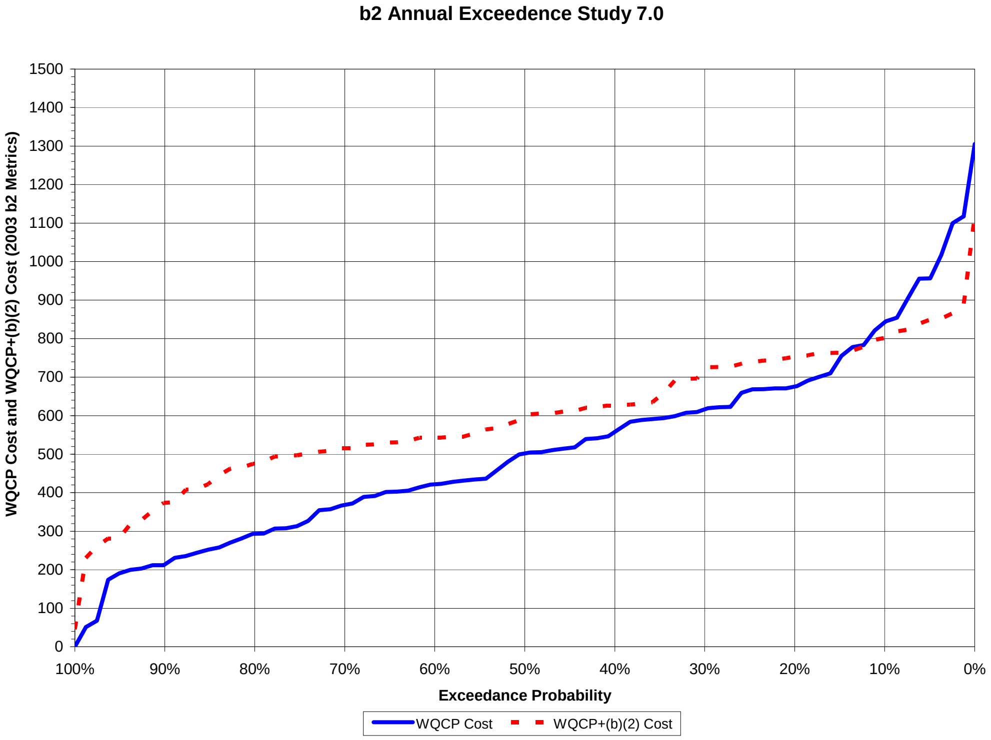

Figure 9-16. Annual WQCP and Total (b)(2) Costs Probability of Exceedance for Study 7.0

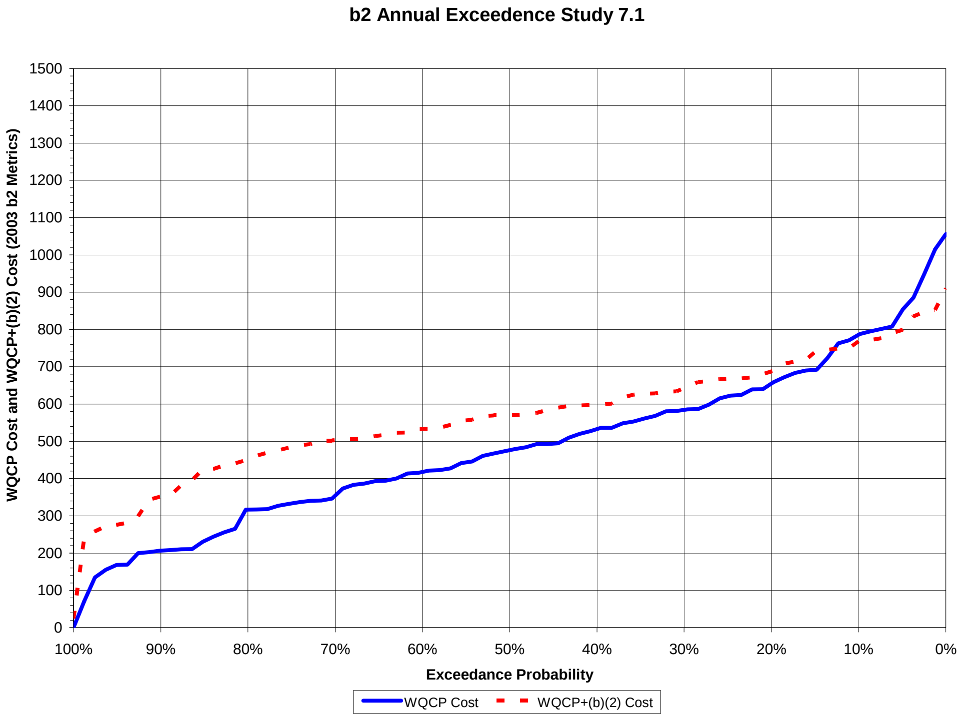

Figure 9-17. Annual WQCP and Total (b)(2) Costs Probability of Exceedance for Study 7.1

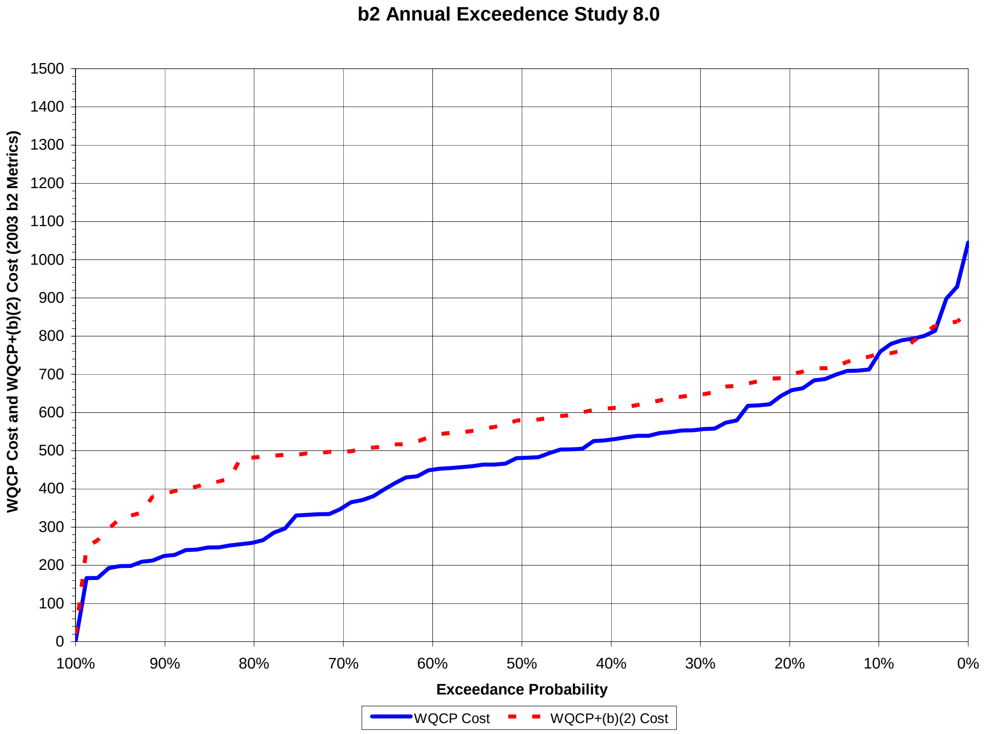

Figure 9-18. Annual WQCP and Total (b)(2) Costs Probability of Exceedance for Study 8.0

Table 9-11. Total (b)(2) Water Requested for Export Actions Versus Amount of (b)(2) Water Used

	Total Water Requested			**Simulated (b)(2) Water Used**		
Study 6.0	**Apr-May VAMP**	**May Shoulder**	**June Ramping**	**Apr-May VAMP**	**May Shoulder**	**June Ramping**
Average	**104**	**32**	**12**	**104**	**22**	**8**
W	**85**	**42**	**16**	**85**	**30**	**8**
AB	**127**	**35**	**12**	**127**	**23**	**8**
BN	**125**	**30**	**11**	**125**	**26**	**11**
D	**111**	**26**	**9**	**111**	**14**	**12**
C	**88**	**18**	**8**	**88**	**8**	**1**
Study 7.0	**Apr-May VAMP**	**May Shoulder**	**June Ramping**	**Apr-May VAMP**	**May Shoulder**	**June Ramping**
Average	102	38	14	102	31	8
W	83	42	16	83	48	8
AB	128	42	14	128	33	13
BN	122	33	11	122	23	12
D	110	34	11	110	15	5
C	84	37	15	84	21	5
Study 7.1	**Apr-May VAMP**	**May Shoulder**	**June Ramping**	**Apr-May VAMP**	**May Shoulder**	**June Ramping**
Average	99	39	15	99	31	10
W	79	42	18	79	50	11
AB	136	42	14	136	27	13
BN	126	40	16	126	26	12
D	97	41	15	97	24	12
C	79	26	7	79	11	1
Study 8.0	**Apr-May VAMP**	**May Shoulder**	**June Ramping**	**Apr-May VAMP**	**May Shoulder**	**June Ramping**
Average	97	40	15	97	33	11
W	80	42	16	77	48	9
Study 8.0	**Apr-May**	**May**	**June**	**Apr-May**	**May**	**June**

	Total Water Requested			Simulated (b)(2) Water Used		
	VAMP	**Shoulder**	**Ramping**	**VAMP**	**Shoulder**	**Ramping**
AB	137	42	14	137	29	13
BN	122	37	15	122	32	13
D	96	41	15	96	25	16
C	74	33	12	74	16	4

Table 9-12. Percent That Possible Occurrences Action Was Triggered

Actions	Study 6.0	Study 7.0	Study 7.1	Study 8.0
Keswick Releases	71%	67%	73%	74%
Whiskeytown Releases	98%	97%	97%	98%
Nimbus Releases	74%	100%	100%	100%
Dec-Jan Export Cuts	NA	NA	NA	NA
VAMP Export Cuts	100%	100%	100%	100%
Late May Export Cuts	76%	89%	91%	93%
Jun Export Cuts	63%	73%	79%	78%
Early Apr Export Cuts	NA	NA	NA	NA
Feb-Mar Export Cuts	NA	NA	NA	NA

Environmental Water Account

This section summarizes the EWA operations for Study 6.0 (i.e., Today EWA: Revised Model/Study 3a Assumptions), Study 7.0 (i.e., Today EWA), Study 7.1 (i.e., Near Future Limited EWA), and Study 8.0 (i.e., Future Limited EWA). Operations are summarized for the following categories:

- Annual costs of EWA actions (i.e., expenditures) measured as export reductions
- Delivery debt status and payback (i.e., adherence to the No Harm Principle)
- Carryover debt conditions from year-to-year
- Annual accrual of EWA assets to mitigate impacts of EWA actions (i.e., water purchases, (b)(2) gains, use of JPOD capacity, wheeling of backed-up water)
- Spilling of carryover EWA debt situated at SWP San Luis
- Annual costs specific to each EWA action measured as export reductions

The annual EWA expenditures for the simulation are shown on Figure 9-19, first as the sum of expenditures associated with winter and spring EWA actions, and second as the expenditures only associated with the spring VAMP action (i.e., EWA Action 3). The Full EWA had annual expenditures ranging from 100,000 af to 600,000 af. whereas both of the Limited EWA studies had annual expenditures ranging from 0 af to 77,000 af. Looking at the VAMP costs it can be seen that for the Full EWA the range of expenditure is 0 af to 235,000 af, but for the Limited EWA nearly all of the costs are associated with EWA.

Another way of viewing annual EWA expenditures is to consider their year-type-dependent averages. The Sacramento River Basin 40-30-30 index was used to classify and sort years. Average annual expenditures by year type are listed in Table 9-13. Comparing Full EWA (Study6.0 and Study 7.0) and Limited EWA (Study 7.1 and Study 8.0) results, the year-type-dependent averages are quite different.

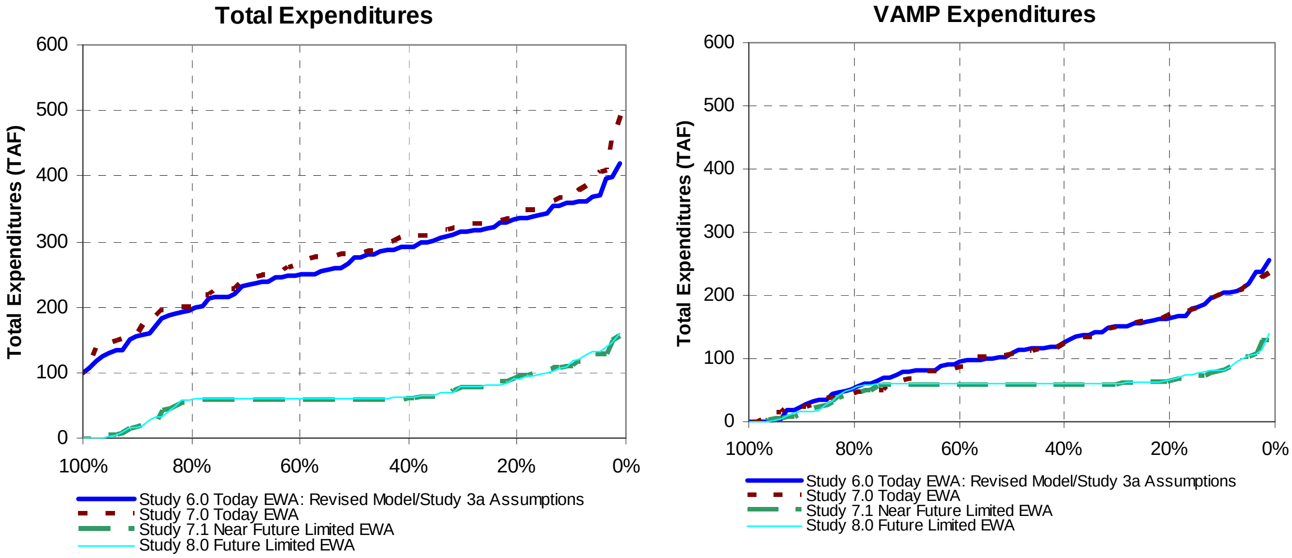

Figure 9-19. Annual EWA expenditures simulated by CalSim-II, measured in terms of export reductions from exports under the EWA Regulatory Baseline relative to exports with EWA operations.

Table 9-13. Annual EWA Expenditures Simulated by CalSim-II, Averaged by Hydrologic Year Type, Defined According to the Sacramento River 40-30-30 Index.

Hydrologic Year Type	Study 6.0 (TAF)	Study 7.0 (TAF)	Study 7.1 (TAF)	Study 8.0 (TAF)
Average	264	279	66	66
Wet	293	315	63	63
Above Normal	306	319	70	77
Below Normal	254	268	69	76
Dry	255	277	88	77
Critical	183	175	34	34

Under limited EWA there are times when the VAMP export reductions are not fully covered by assets acquired from the Yuba Accord and other operational assets. However, for the most part VAMP export reductions could be met most of the time. Figure 9-20 shows exceedance plots of the April 15 to April 30 and May 1 to May 15 periods that cover the assumed time for the VAMP in the model. The figure shows the amount of time in which the total exports meet the export limits described in the San Joaquin River Agreement in years when a Vernalis flow target is specified. Since the agreement does not specifically prescribe an export limit for years in which the San Joaquin River flow is greater than 7000 cfs these simulated years are not included in the figure. In addition, when the Vernalis flow target is 7000 cfs, the SJRA specifies two possible export rates, 1500 cfs and 3000 cfs. For the purposes of Figure 9-20 an export limit of 3000 cfs was assumed for every simulated year when the Vernalis target is 7000 cfs.

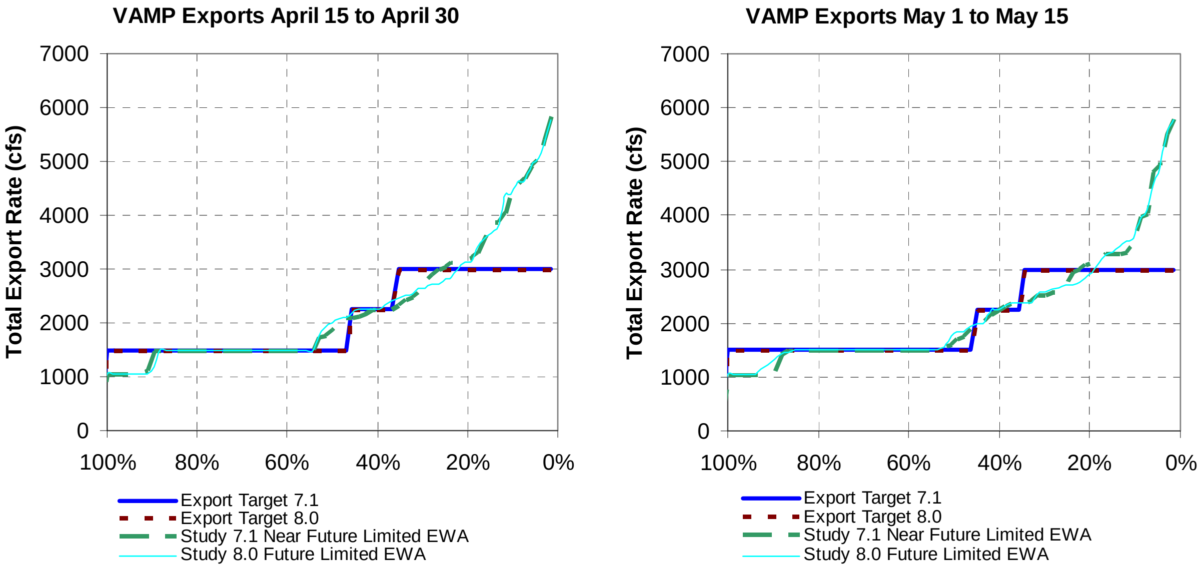

Figure 9-20Combined Banks and Jones export rate simulated by CalSim-II, during the April and May VAMP period compared to export target flow specified in the San Joaquin River Agreement.

The measure of “deliveries debt payback” is the key indicator of whether the simulated EWA operations adhere to the No Harm to Deliveries principle set forth in the CALFED ROD. In CalSim-II modeling, SOD delivery debt is assessed in the month after it occurs.

A debt is to be repaid in full upon assessment through dedication of an EWA asset available SOD (either as a SOD purchase planned for that month, a wheeled NOD asset planned for that month, or an EWA San Luis storage withdrawal that month). Instances when SOD delivery debt could not be repaid in full can be seen through post-simulation analysis of CalSim-II results. As shown in Table 9-14 there were no instances of not adhering to the “No Harm Principle” for Study 7.0, Study 7.1 and Study 8.0. Study 7.1 and Study 8.0 assumed a Limited EWA and no debt was allowed to accumulate.

Table 9-14. Instances of not Adhering to the EWA “No Harm Principle” (i.e., not repaying delivery debt in full upon assessment), Simulated by CalSim-II.

Delivery Debt Account	Study 6.0 (Full EWA)	Study 7.0 (Full EWA)	Study 7.1 (Limited EWA)	Study 8.0 (Limited EWA)
CVP South of Delta	None	None	No debt allowed	No debt allowed
SWP South of Delta	None	None	No debt allowed	No debt allowed

A key feature of simulated and real EWA operations that enable increased flexibility to mitigate the impacts of EWA actions is the allowance for carryover debt. In the CalSim-II modeling, because of the model structure, Figure 9-3, the annual interruption of the simulated EWA operational baseline necessitates special measures to account for carryover debt relative to debt caused by this year’s actions (i.e., “new debt” in CalSim-II semantics). The result of these measures is separate debt accounts for carryover and new debt. Unpaid new debt ultimately gets rolled over into the carryover debt account, which can represent one or more years of unpaid debt.

The rollover of new debt into the carryover debt account occurs in November. Results on carryover debt conditions at total CVP/SWP San Luis are shown on Figure 9-21 for the 82 Octobers and Novembers simulated. These carryover debt conditions are at a maximum in November, after which they are managed to a minimum in October through dedication of physical EWA assets available SOD or spilling of carryover debt at SWP San Luis.

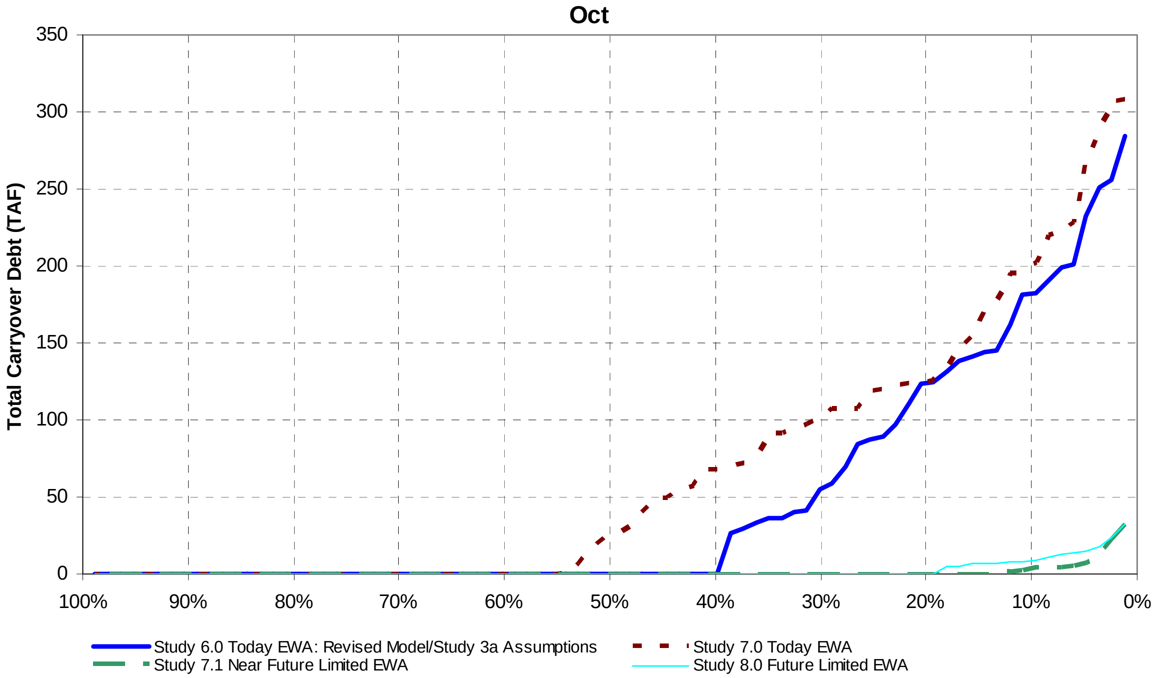

Figure 9-21. Combined Carryover Debt at CVP and SWP San Luis, Simulated in CalSim- II, at the End (Oct) and Start (Nov) of the Carryover Debt Assessment Year

The comparative ranges of acquired EWA assets under Full EWA (Study 6.0 and Study 7.0) and Limited EWA (Studies 7.1 and 8.0) are summarized on Figure 9-22. In Figure 9-22 the “Total Acquired Assets” includes water purchases and operational assets (i.e., EWA acquisition of 50 percent of SWP gains from B2 releases, EWA conveyance of Delta Surplus flows using 50 percent of JPOD capacity or summer dedicated capacity, EWA conveyance of backed-up water caused by Spring EWA actions on exports.

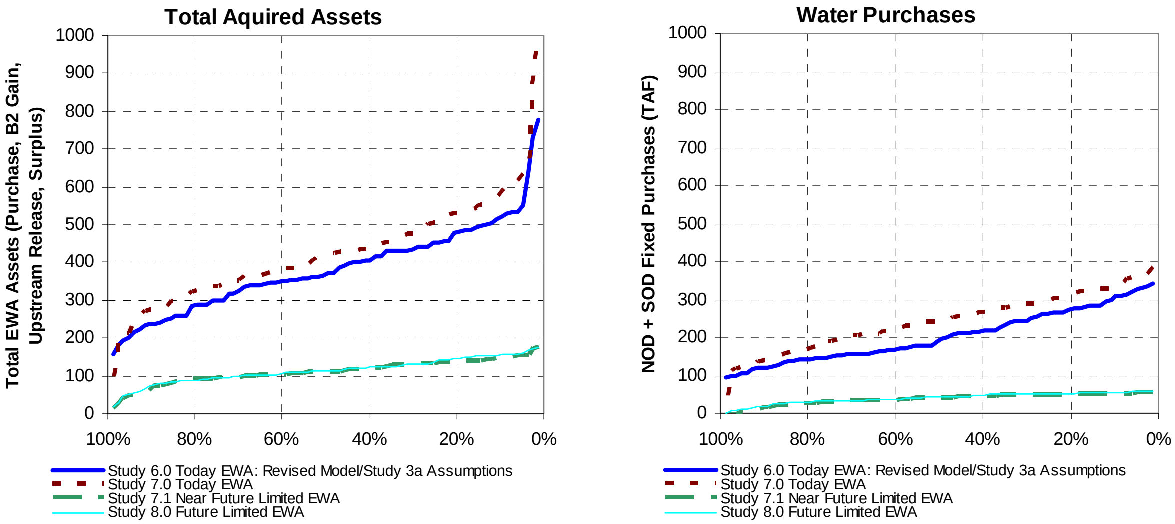

Figure 9-22. Annual EWA assets simulated in CalSim-II.

A unique tool for managing carryover debt at SWP San Luis is debt spilling, described earlier. In CalSim-II, carryover debt conditions need to be present and severe enough to trigger the use of this tool under the spill conditions that were outlined earlier. Also note that there is a semantics difference between what is called “spill” in CalSim-II and what is called “spill” by EWAT. CalSim-II only designates erasing of carryover debt at SWP San Luis, or reservoir filling in NOD reservoirs as “spilling” debt; it does not designate “pumping-to-erase” new debt at San Luis as “spill,” even though this is a term sometimes used by EWAT. That distinction noted, the occurrence of carryover debt spilling at SWP San Luis is depicted on Figure 9-23.

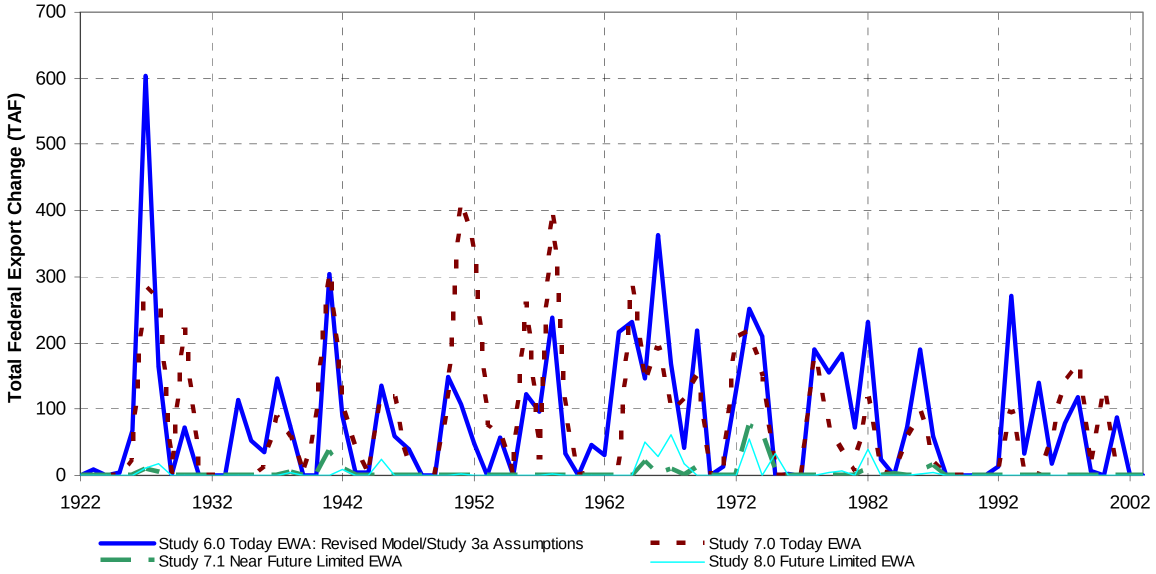

Figure 9-23. Annual Carryover-debt Spilling at SWP San Luis, Simulated in CalSim-II.

EWA action-specific expenditures for Winter Export Reductions are expected to be 50,000 af for each month in which they are implemented, according to modeling assumptions. Generally, this is the case, as indicated by simulated export reductions measured between Step 4 and Step 5 in Full EWA study (Figure 9-24). The action is always taken in December and January, and it is also taken in February if the Sacramento River 40-30-30 Index defines the year to be Above Normal or Wet. Simulation results show that export reductions are always as expected for January and February and nearly always as expected for December (approximately 95 percent of the years).

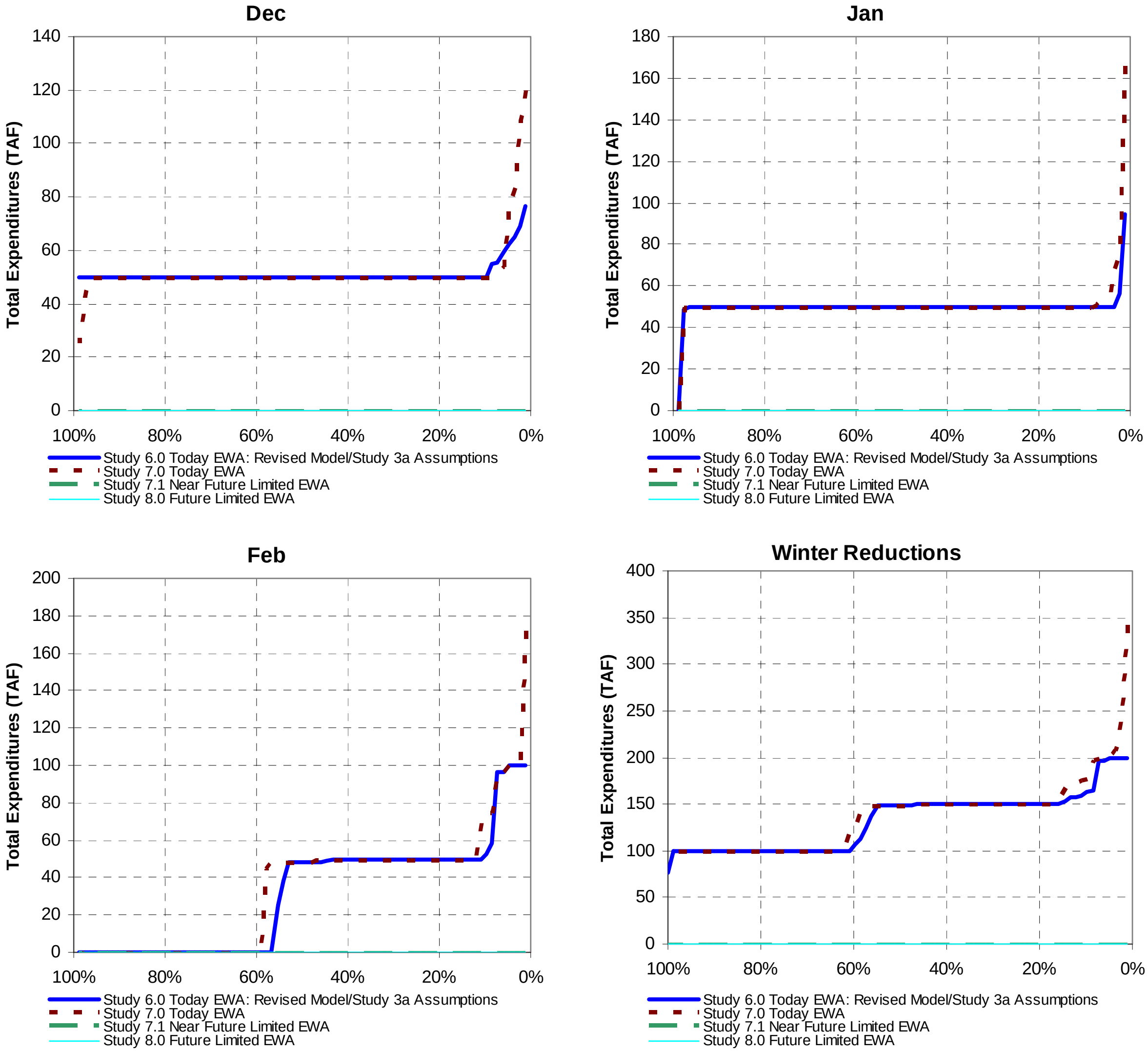

Figure 9-24. Simulated Export Reductions Associated with Taking EWA Action 2 (i.e., Winter Export Reductions). Note that Export Reductions for Studies 7.1 and 8.0 are zero.

Expectations for spring actions expenditures are more difficult to predict prior to simulation compared to expenditures for winter actions. This is because spring actions are not linked to spending goals, but are instead linked to target export restriction levels related to VAMP. Results show that action-specific export costs for spring actions are slightly higher in the Full EWA study compared to the Limited EWA studies (Figure 9-25 through Figure 9-27). Moreover, the frequency of implementing June export reductions only occurs in the Full EWA.

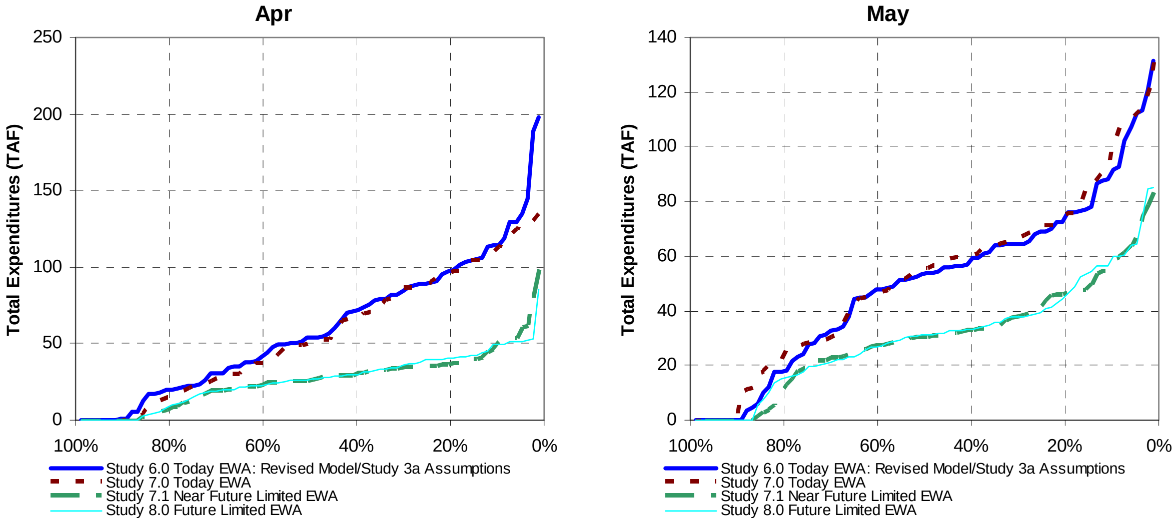

Figure 9-25 – **Simulated Export Reductions Associated with Taking EWA Action 3 (i.e., VAMP-related restrictions).**

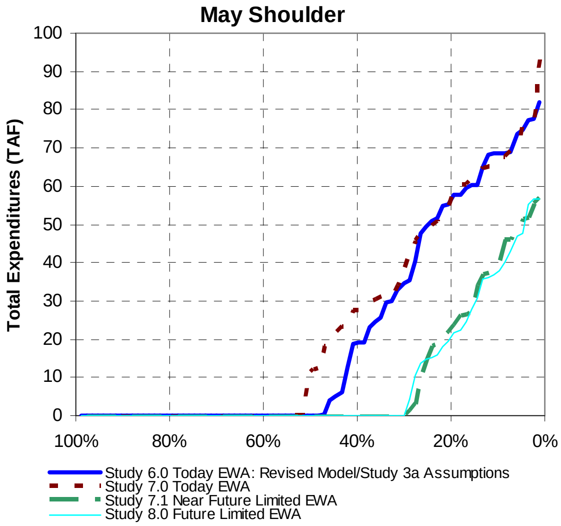

Figure 9-26 – **Simulated Export Reductions Associated with Taking EWA Action 5 (i.e., extension of VAMP-related restrictions into May 16–May 31 (i.e., the May Shoulder)).**

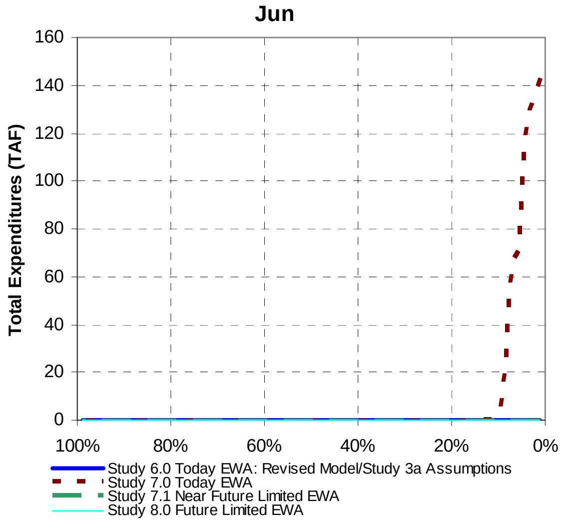

Figure 9-27– Simulated Export Reductions Associated with Taking EWA Action 6 (i.e., representation of June "ramping" from May Shoulder restriction to June Export-to-Inflow restriction).

The additional 500 cfs summer (July through September) capacity is an important element of the full EWA, limited EWA, and theYuba Accord. Assets acquired North of the Delta from theYuba Accord, or stored in upstream reservoirs can be pumped to repay previous fishery imposed export reductions. Much of the time this repayment would need to occur before the end of September to reduce the chance of impacting project deliveries. Figure 9-28 shows the simulated use of the additional 500 cfs and the total assets pumped through the use of this additional capacity. Generally, the limited EWA studies use the full capacity less than 25 percent of the time, while the full EWA studies use the full capacity less than 35 percent of the time.

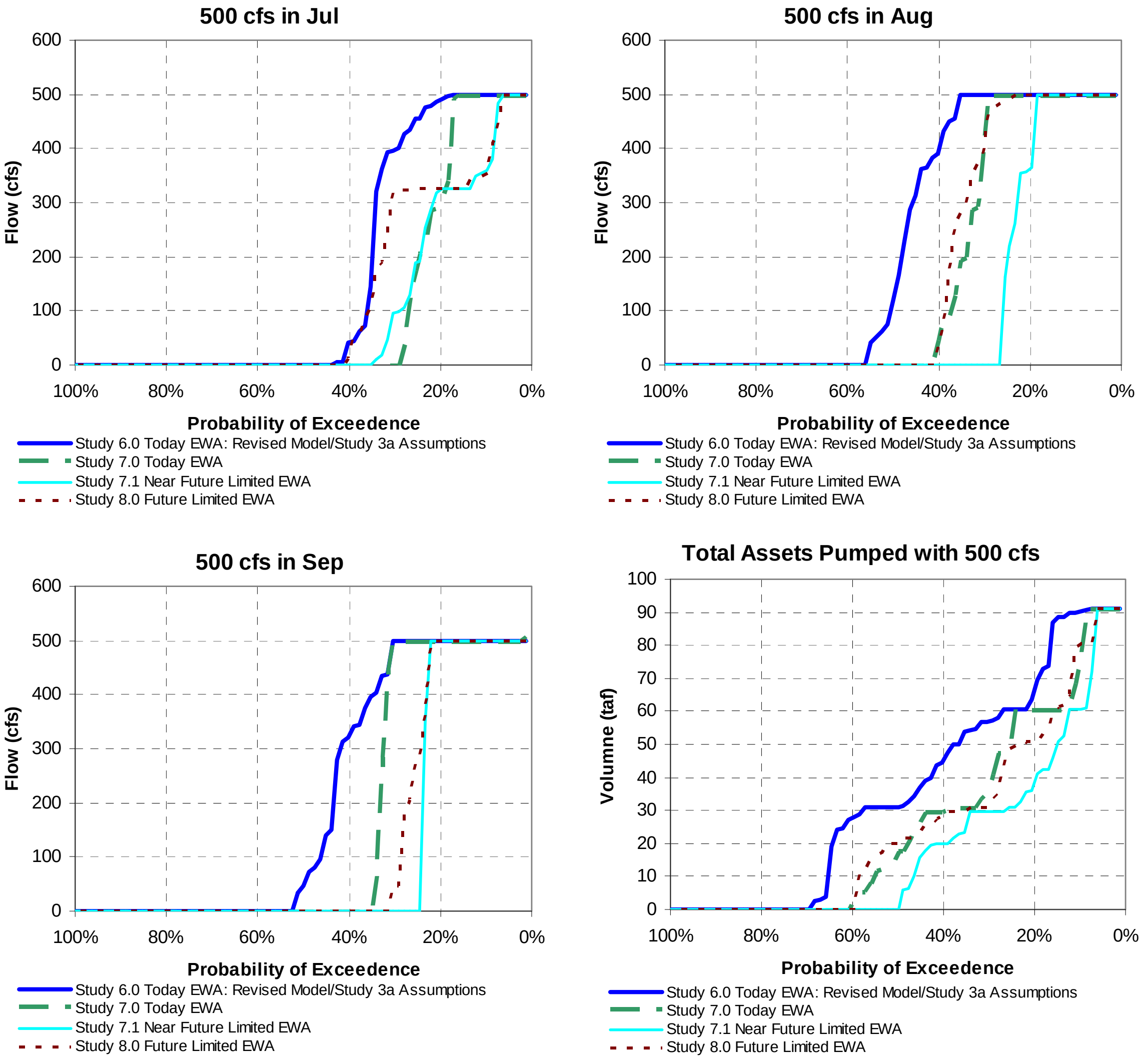

Figure 9-28 Simulated use of additional 500 cfs Banks fishery capacity in summer months (Jul, Aug, and Sep) and total assets pumped using additional capacity (taf).

Delta Hydrodynamic Results

The DSM2-Hrodro was run from water years 1976 to 1991 and output was provided for a number of locations in the Delta. Figure 9-29 shows a map of the Delta and all of the available output locations as well as the direction of positive flow and velocity for each location. Table 9-15 lists these output locations along with the common name, representative DSM2 channel number and distance in channel. All of the results from DSM2-Hydro are provided in spreadsheets, but for purposes of this BA and Appendix G, only four sites were selected for discussion. These four sites were generally a combination of flows that represent an imaginary boundary internal to the Delta. These four sites were:

- Cross Delta flow – a combination of Georgiana Slough, North Fork of Mokelumne, and South Fork of the Mokelumne (GEORGIANA_SL, NORTH_FORK_MOKE, and RSMKL008 as respectively labeled in Figure 9-29).
- QWest flow – a combination of San Joaquin River at Blind Point, Three Mile Slough, and Dutch Slough (RSAN014,SLTRM004, and SLDUT007 as respectively labeled in Figure 9-29).
- Old and Middle River flow – a combination of Old River at Bacon Island and Middle River at Middle River (ROLD024, and RMID015 as respectively labeled in Figure 9-29).
- Old River at Head – described by a single output location ROLD074 as labeled in Figure 9-29.

One location from each of the groups was used to give an indication of the average velocity. From the Cross Delta group GEORGIANA_SL is presented for velocity. From the Qwest group RANS014 is presented for velocity, and from Old and Middle River RMID015 is presented.

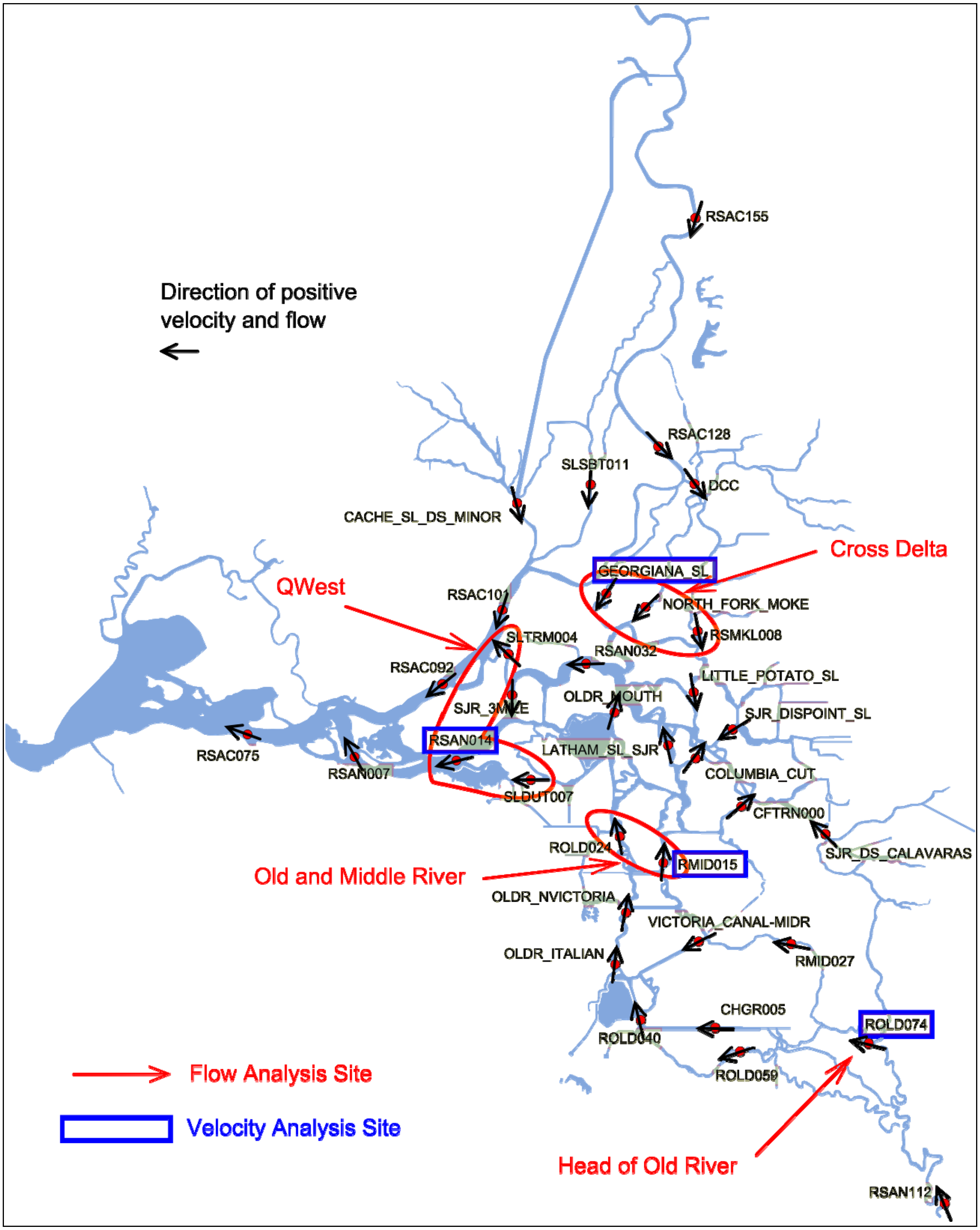

Figure 9-29. DSM2-Hydro locations of output for flow (cfs) and velocity (ft/s). Arrows represent the direction of positive flow and velocity.

Table 9-15. Definitions for the DSM2 output

DSM2 Output Name	Channel	Distance	Common Name
CFTRN000	172	727	Turner Cut
CHGRL005	211	1585	Grant Line Canal (West Position)
RMID015	144 - 145	838	Middle River at Middle River (west channel)
RMID027	133	3641	Middle River at Tracy Blvd
ROLD014	117	0	Old River at Holland Cut
ROLD024	106	2718	Old River at Bacon Island
ROLD040	82	2609	Old River at Clifton Court Ferry
ROLD059	71	3116	Old River at Tracy Road
ROLD074	54	735	Head of Old River
RSAC075	437	11108	Sacramento River at Mallard Island
RSAC092	434	435	Sacramento River at Emmaton
RSAC101	430	9684	Sacramento River at Rio Vista
RSAC128	421	8585	Sacramento River above Delta Cross Channel
RSAC155	414	11921	Sacramento River at Freeport
RSAN007	52	366	San Joaquin River at Antioch
RSAN014	49	9570	San Joaquin River at Blind Point
RSAN024	47	8246	San Joaquin River at Bradford Isl.
RSAN032	349	9672	San Joaquin River at San Andreas Landing
RSAN058	20	2520	San Joaquin River at Stockton Ship Channel
RSAN112	17	4744	San Joaquin River at Vernalis
RSMKL008	344	7088	South Fork Mokelumne at Staten Island
SLDUT007	274	7351	Dutch Slough
SLSBT011	385	2273	Steamboat Slough
SLTRM004	310	540	Three Mile Slough
DCC	365	0	Delta Cross Channel
COLUMBIA_CUT	160	50	Columbia Cut
SJR_DS_CALAVARAS	21	0	San Joaquin River downstream Calaveras River
SJR_3MILE	49	9570	San Joaquin River at Three Mile Slough

DSM2 Output Name	Channel	Distance	Common Name
OLDR_ITALIAN	88	0	Old River at Italian Slough
OLDR_NVICTORIA	91	4119	Old River at North Victoria Canal
OLDR_MOUTH	124	7062	Mouth of Old River
LATHAM_SL_SJR	161	10808	Latham Slough at San Joaquin River
VICTORIA_CANAL_MIDR	226	4153	Victoria Canal at Middle River
SJR_DISPOINT_SL	314	8130	Disappointment Slough at San Joaquin River
LITTLE_POTATO_SL	325	9962	Little Potato Slough
NORTH_FORK_MOKE	363	6133	North Fork Mokelumne River
GEORGIANA_SL	371	7766	Georgiana Slough
CACHE_SL_DS_MINOR	398	0	Cache Slough downstream Minor Slough
OMR	144 - 145 + 106	--	Old and Middle River
QWEST	274 + 49 + 310	--	Western Flow (QWEST)
XDELTA	371 + 363 + 344	--	Cross Delta Flow

The DSM2-Hydro results were aggregated from a fifteen-minute time-step to a daily average. A Godin filter was first applied to the data to remove the tidal variations, and then a daily average of the filtered data was applied. This is the same process that the United States Geological Survey (USGS) uses to determine daily averages for locations under tidal influence. The flow results are presented in Table 9-16 and velocity results are presented in Table 9-17. Both tables present the minimum, 25 percentile, median, 75 percentile, and maximum value for water-years 1976 to 1991, broken down into groups representing annual quarters, and year type groups. The monthly output was grouped into the annual quarters: January through March (Jan-Mar), April through June (Apr-Jun), July through September (Jul-Sep), and October through December (Oct-Dec). The year types were grouped into two representative groups: Wet and Above Normal (W-AN), and Below Normal, Dry and Critical (C-D-BN). For regional flows that cross more than one individual location, for example Old and Middle River includes two output locations, a simple time period summation was conducted.

Appendix G presents DSM2-Hydro results in graphical form. Box plots show the minimum, 25 percentile, median, 75 percentile, and maximum value. Along with the box plots results are also displayed in exceedence plots that show the percent of time in which a certain value was exceeded.

Table 9-16. DSM2-Hydro tidally filtered daily average flow for water-years 1976 to 1991. Shading indicates negative (landward) flows. Positive flows are towards the ocean.

	Year	Month	Study 6.0					Study 7.0					Study 7.1					Study 8.0				
Name	Types	Range	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Head of Old River	W AN	Jan-Mar	1433	3772	8297	9708	17657	1433	3782	8322	9726	17688	1195	3712	8073	9555	16726	1180	3676	8047	9557	16691
		Apr-Jun	1292	3669	5517	9014	10450	1276	3690	5544	9026	10491	0	3601	5670	8719	10098	0	3598	5659	8646	10119
		Jul-Sep	830	1354	1610	3731	9939	833	1339	1615	3732	9956	451	1736	1958	3964	9582	450	1766	1963	3924	9588
		Oct-Dec	225	715	1539	3545	9992	202	721	1544	3544	10006	141	301	857	1556	9634	126	299	851	1545	9621
	C D BN	Jan-Mar	728	1085	1441	1696	4776	728	1093	1441	1694	4785	610	1046	1307	1593	4561	517	964	1254	1564	4516
		Apr-Jun	202	411	657	893	4497	176	409	650	917	4497	0	0	663	1092	4114	0	0	569	1007	4100
		Jul-Sep	159	341	626	803	1294	110	332	616	797	1286	185	301	366	451	1263	186	302	353	447	1171
		Oct-Dec	249	568	1001	1222	1745	257	582	1003	1242	1742	155	247	410	1066	1624	147	241	407	1083	1589
Old and Middle River	W AN	Jan-Mar	-9811	-6197	-2189	3590	23765	-9811	-6343	-2271	3508	22248	-10969	-6522	-2063	4484	22446	-10993	-5916	-2654	3720	22029
		Apr-Jun	-8033	-3638	-704	1326	9011	-8041	-4094	-662	1613	8614	-7621	-3870	-2607	754	8392	-7825	-3851	-2645	797	8378
		Jul-Sep	-11481	-9831	-8699	-7877	1425	-11285	-9669	-8482	-7576	1469	-10871	-9188	-8070	-7439	1268	-11402	-9571	-8727	-7826	1312
		Oct-Dec	-10847	-8723	-7753	-4430	9519	-10845	-8793	-7908	-3575	5659	-11664	-10197	-9060	-3196	6273	-11635	-10192	-9062	-3043	6153
	C D BN	Jan-Mar	-10175	-7812	-5800	-2408	544	-10174	-7724	-5642	-3220	64	-11482	-7540	-5743	-4164	-340	-11481	-8348	-5851	-3640	682
		Apr-Jun	-9451	-4413	-1967	-1345	2021	-9709	-4702	-1997	-1382	2020	-9662	-4514	-2559	-1994	-593	-9785	-4221	-2592	-1990	-241
		Jul-Sep	-12031	-9614	-6523	-4991	-3129	-12203	-8860	-7152	-5059	-1123	-12383	-9010	-5839	-4278	-1150	-12393	-9432	-5454	-3986	-912
		Oct-Dec	-10768	-8355	-6918	-5595	-2106	-10766	-8718	-7312	-6188	-2134	-11992	-9625	-8022	-5652	-2870	-11974	-9313	-7789	-5600	-1811
QWEST	W AN	Jan-Mar	-5104	8082	19171	33695	72635	-5164	7431	19078	32600	70980	-6395	6555	18054	33265	71822	-6493	6484	17660	32651	71360
		Apr-Jun	-1869	5739	8228	17578	41974	-1937	5409	7970	18127	41570	-3594	4921	7265	17684	41546	-3788	4871	7161	17730	41550
		Jul-Sep	-6667	-2124	-971	1007	17117	-5627	-2076	-708	1794	21810	-5696	-2060	-837	1944	21523	-6123	-2571	-1299	1468	21335
		Oct-Dec	-13103	-1699	500	5628	45661	-12124	-1855	600	5608	41532	-14146	-2360	243	5198	42381	-14114	-2368	245	5223	42274
	C D BN	Jan-Mar	-9637	-2293	-63	2040	11260	-9891	-2182	-281	1926	10678	-11004	-2390	-489	1424	11640	-11159	-2353	-433	1614	11391
		Apr-Jun	-6869	-425	1096	2851	12199	-7266	-563	1059	2782	11992	-7095	-624	881	2633	10704	-7343	-736	904	2669	10655
		Jul-Sep	-8152	-3057	-1656	-408	3460	-7810	-2788	-1614	-305	4657	-8359	-2708	-1166	274	4670	-8497	-2921	-1217	313	4669
		Oct-Dec	-11901	-2510	-1096	247	6832	-11824	-2742	-1389	-56	6723	-12941	-3048	-1462	-79	5480	-12743	-2965	-1400	54	5925
Cross Delta	W AN	Jan-Mar	4817	9224	13431	16622	23914	4753	9174	13388	16632	23917	4818	8857	13351	16402	23672	4734	8895	13346	16435	23691
		Apr-Jun	3315	4402	6699	9147	18430	3286	4422	6518	9124	18437	3038	4375	6365	9149	18412	3005	4337	6295	9075	18448
		Jul-Sep	5178	6436	7109	7803	10081	5543	6539	7028	7856	10955	5358	6375	6911	7933	10666	5451	6564	7066	8018	10484
		Oct-Dec	2104	5156	7152	9344	17461	2111	5578	7232	9207	17475	2129	5516	6971	9198	17451	2118	5555	6768	9191	17483
	C D BN	Jan-Mar	1672	3036	3888	5333	10418	1984	3124	4023	5693	10134	2039	3367	4009	5799	10368	2080	3312	3977	5661	10072
		Apr-Jun	1502	2434	3165	4839	7405	1510	2421	3122	4673	7966	1443	2406	3119	4512	8072	1530	2439	3143	4371	8183
		Jul-Sep	3925	5058	5795	7183	8860	3638	4986	5814	6758	8513	3371	4382	5540	6684	8740	2953	4404	5410	6898	8900
		Oct-Dec	1980	4069	5266	5824	9625	1886	4189	5495	6022	9518	1962	4083	5197	6000	9490	1963	4076	5195	5976	9512

Table 9-17. DSM2-Hydro tidally filtered daily average velocity for water-years 1976 to 1991. Shading indicates negative (landward) velocities. Positive velocities are towards the ocean.

Name	Year Types	Month Range	Study 6.0					Study 7.0					Study 7.1					Study 8.0				
			Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Head of Old River	W AN	Jan-Mar	0.89	1.70	2.55	2.61	3.29	0.89	1.70	2.56	2.62	3.29	0.74	1.68	2.52	2.58	3.19	0.73	1.68	2.52	2.58	3.19
		Apr-Jun	0.69	1.66	1.99	2.62	2.66	0.68	1.66	2.00	2.62	2.66	0.00	1.66	2.13	2.57	2.62	0.00	1.66	2.13	2.56	2.62
		Jul-Sep	0.50	0.74	0.85	1.56	2.68	0.50	0.74	0.85	1.56	2.68	0.29	0.98	1.07	1.73	2.63	0.30	1.00	1.07	1.72	2.63
		Oct-Dec	0.14	0.44	0.83	1.52	2.67	0.13	0.44	0.84	1.52	2.67	0.09	0.21	0.53	0.88	2.63	0.08	0.20	0.53	0.88	2.63
	C D BN	Jan-Mar	0.50	0.68	0.88	0.99	1.94	0.50	0.68	0.88	0.99	1.94	0.40	0.64	0.79	0.92	1.89	0.34	0.59	0.76	0.91	1.88
		Apr-Jun	0.12	0.27	0.41	0.57	1.89	0.11	0.27	0.41	0.60	1.89	0.00	0.00	0.42	0.67	1.79	0.00	0.00	0.37	0.61	1.78
		Jul-Sep	0.09	0.20	0.38	0.48	0.72	0.07	0.19	0.37	0.47	0.71	0.12	0.20	0.24	0.29	0.76	0.12	0.19	0.23	0.29	0.72
		Oct-Dec	0.16	0.34	0.59	0.75	0.99	0.17	0.35	0.59	0.76	0.99	0.10	0.16	0.28	0.67	0.92	0.10	0.16	0.27	0.67	0.90
Middle River at Middle River	W AN	Jan-Mar	-0.26	-0.16	-0.06	0.09	0.58	-0.26	-0.17	-0.06	0.09	0.54	-0.29	-0.17	-0.05	0.12	0.54	-0.29	-0.16	-0.07	0.10	0.53
		Apr-Jun	-0.22	-0.09	-0.01	0.04	0.23	-0.22	-0.11	-0.01	0.05	0.22	-0.21	-0.10	-0.07	0.03	0.22	-0.21	-0.10	-0.07	0.03	0.22
		Jul-Sep	-0.31	-0.26	-0.23	-0.21	0.04	-0.30	-0.26	-0.23	-0.20	0.04	-0.29	-0.25	-0.21	-0.19	0.04	-0.31	-0.26	-0.23	-0.20	0.04
		Oct-Dec	-0.29	-0.23	-0.21	-0.12	0.25	-0.29	-0.24	-0.21	-0.10	0.15	-0.31	-0.28	-0.25	-0.09	0.16	-0.31	-0.28	-0.25	-0.08	0.16
	C D BN	Jan-Mar	-0.27	-0.21	-0.15	-0.06	0.02	-0.27	-0.21	-0.15	-0.08	0.01	-0.31	-0.20	-0.15	-0.11	-0.01	-0.31	-0.23	-0.16	-0.10	0.02
		Apr-Jun	-0.25	-0.12	-0.05	-0.03	0.06	-0.26	-0.13	-0.05	-0.04	0.06	-0.26	-0.12	-0.07	-0.05	-0.02	-0.26	-0.11	-0.07	-0.05	-0.01
		Jul-Sep	-0.33	-0.26	-0.17	-0.13	-0.08	-0.34	-0.24	-0.19	-0.13	-0.03	-0.34	-0.24	-0.15	-0.11	-0.03	-0.34	-0.25	-0.14	-0.11	-0.02
		Oct-Dec	-0.29	-0.22	-0.19	-0.15	-0.06	-0.29	-0.24	-0.20	-0.16	-0.06	-0.33	-0.26	-0.22	-0.15	-0.08	-0.33	-0.25	-0.21	-0.15	-0.05
San Joaquin River at Blind Point	W AN	Jan-Mar	0.00	0.16	0.28	0.42	0.86	0.00	0.15	0.28	0.42	0.85	-0.01	0.14	0.27	0.42	0.85	-0.01	0.14	0.26	0.41	0.85
		Apr-Jun	0.05	0.12	0.15	0.24	0.50	0.05	0.12	0.15	0.25	0.50	0.03	0.12	0.14	0.24	0.50	0.03	0.12	0.14	0.24	0.50
		Jul-Sep	-0.02	0.04	0.06	0.08	0.24	0.00	0.04	0.06	0.09	0.28	-0.01	0.04	0.06	0.09	0.28	-0.01	0.04	0.05	0.08	0.28
		Oct-Dec	-0.06	0.05	0.07	0.14	0.56	-0.05	0.05	0.07	0.14	0.52	-0.07	0.04	0.07	0.14	0.53	-0.07	0.04	0.07	0.14	0.53
	C D BN	Jan-Mar	-0.04	0.05	0.07	0.09	0.20	-0.03	0.05	0.07	0.09	0.19	-0.04	0.04	0.06	0.09	0.20	-0.06	0.04	0.06	0.09	0.20
		Apr-Jun	0.00	0.06	0.08	0.10	0.20	0.00	0.06	0.08	0.09	0.20	0.00	0.06	0.07	0.09	0.19	0.00	0.06	0.07	0.09	0.19
		Jul-Sep	-0.02	0.03	0.05	0.06	0.10	-0.02	0.03	0.05	0.06	0.12	-0.03	0.03	0.05	0.07	0.12	-0.03	0.03	0.05	0.07	0.12
		Oct-Dec	-0.06	0.04	0.05	0.07	0.13	-0.06	0.04	0.05	0.06	0.13	-0.08	0.03	0.05	0.06	0.12	-0.07	0.04	0.05	0.06	0.12
Georgiana Slough	W AN	Jan-Mar	1.01	1.99	2.45	2.60	2.74	1.00	1.99	2.44	2.60	2.74	1.02	1.99	2.44	2.60	2.74	1.01	1.99	2.45	2.60	2.74
		Apr-Jun	0.66	0.87	1.02	1.61	2.71	0.71	0.87	1.01	1.61	2.71	0.67	0.88	1.01	1.59	2.71	0.65	0.87	1.01	1.60	2.71
		Jul-Sep	0.68	0.79	0.85	0.94	1.41	0.70	0.78	0.83	0.94	1.38	0.64	0.76	0.81	0.95	1.37	0.67	0.79	0.83	0.95	1.36
		Oct-Dec	0.51	0.73	1.00	1.69	2.76	0.51	0.74	1.00	1.81	2.76	0.42	0.75	1.00	1.73	2.76	0.39	0.75	1.00	1.66	2.76
	C D BN	Jan-Mar	0.45	0.84	1.03	1.41	2.40	0.68	0.89	1.03	1.37	2.35	0.68	0.91	1.07	1.34	2.11	0.60	0.88	1.05	1.32	2.08
		Apr-Jun	0.56	0.73	0.82	0.91	1.49	0.56	0.73	0.83	0.91	1.49	0.54	0.74	0.85	0.91	1.42	0.57	0.70	0.85	0.92	1.42
		Jul-Sep	0.54	0.66	0.74	0.87	1.06	0.54	0.65	0.73	0.83	1.02	0.50	0.60	0.70	0.83	1.05	0.47	0.60	0.70	0.84	1.06
		Oct-Dec	0.54	0.67	0.73	0.89	1.59	0.53	0.70	0.76	0.91	1.56	0.52	0.69	0.75	0.89	1.58	0.53	0.67	0.74	0.88	1.59

DSM2-PTM was run for each month in water-years 1976 to 1991. In each simulation 1000 particles were injected over a period of 24 hours at the nodes described in Table 9-18. Particles were injected starting at the beginning of the forth day of each month. The particles were then tracked until the end of the twenty-fifth day, so the particle locations were reported after approximately twenty-one days. The particles were counted at each of the output locations in Table 9-19. These output locations represent the major locations where particles could go. “Past Chipps” represents the percentage of particles that travel past Chipps Island and into the Suisun Bay. “Exports” represents the combined percentage of particles that end up in Banks Pumping Plant and Jones Pumping Plant. “Other Diversion” represents the combined percentage of particles that end up in the Contra Costa Water District diversions on Old River and Rock Slough, North Bay Aqueduct, and agricultural diversions. The particles that remain in the Delta are grouped into two groups “In North Delta” and “In South Delta”. The delineation line between North and South is shown in Figure 9-30.

For the purposes of this document only three injection locations are presented, however output for all of the injection locations are available in the spreadsheets provided in Appendix G. The injection locations selected for presentation were the San Joaquin River at Mossdale (node 7), Little Potato Slough (node 249), and Sacramento River at Rio Vista (node 350).

The PTM results are presented in Table 9-20 for the injection at node 7, Table 9-21 for the injection at node 249, and Table 9-22 for the injection at node 350. The three tables present the minimum, 25 percentile, median, 75 percentile, and maximum value for water-years 1976 to 1991, broken down into groups representing annual quarters, and year type groups. The monthly output was grouped into the annual quarters: January through March (Jan-Mar), April through June (Apr-Jun), July through September (Jul-Sep), and October through December (Oct-Dec). The year types were grouped into two representative groups: Wet and Above Normal (W-AN), and Below Normal, Dry and Critical (C-D-BN).

Appendix G presents DSM2-PTM results in graphical form. Box plots show the minimum, 25 percentile, median, 75 percentile, and maximum value. Results are also displayed in exceedence plots that show the percent of time in which a certain value was exceeded. Additionally graphical comparisons are made between percent of particles at the exports to Old and Middle River flow, Qwest flow, and Cross Delta flow.

Table 9-18. Injection Locations

Node	Common Name
335	Sacramento River at Freeport
341	Sacramento River above Cross Channel
321	Cache Slough
350	Sacramento River at Rio Vista
353	Sacramento River at Emmaton
355	Sacramento River at Collinsville

Node	Common Name
45	San Joaquin River at Blind Point
272	Mokelumne River near San Joaquin River
249	Little Potato Slough
21	San Joaquin River at Stockton
7	San Joaquin River at Mossdale

Table 9-19. PTM Output

Name	Description
Past Chipps	Particles that pass Chipps Island
In North Delta	Particles that remain in the Northern Delta (Figure 9-30)
In South Delta	Particles that remain in the Southern Delta (Figure 9-30)
Exports	Combined SWP and CVP exports
Other Diversion	Agricultural Diversions, CCWD Diversions, and North Bay Aqueduct

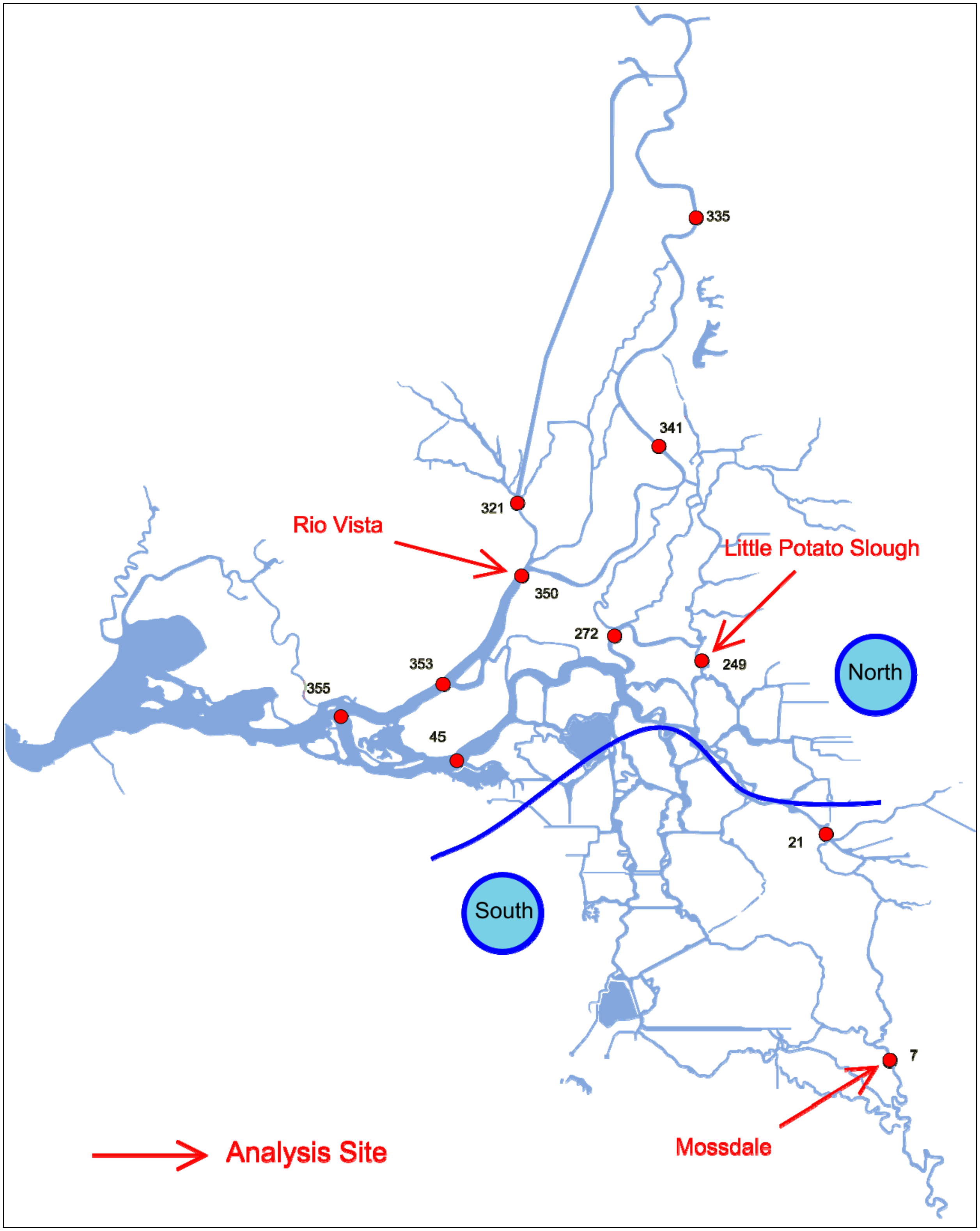

Figure 9-30. DSM2-PTM locations for particle injection.

Table 9-20. Percent particle fate percentiles after 21 days for particle injection at node 7.

	Year	Month	Study 6.0					Study 7.0					Study 7.1					Study 8.0				
Name	Types	Range	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Past Chipps	W AN	Jan-Mar	0	2	35	60	91	0	2	36	57	89	0	2	38	61	91	0	2	36	58	91
		Apr-Jun	0	1	5	36	77	0	1	5	39	76	0	1	4	38	76	0	1	4	39	76
		Jul-Sep	0	0	0	0	40	0	0	0	0	43	0	0	0	0	44	0	0	0	0	43
		Oct-Dec	0	0	0	0	80	0	0	0	0	67	0	0	0	1	69	0	0	0	0	68
	C D BN	Jan-Mar	0	0	0	0	3	0	0	0	0	2	0	0	0	0	5	0	0	0	0	4
		Apr-Jun	0	0	0	0	5	0	0	0	0	2	0	0	0	0	10	0	0	0	0	9
		Jul-Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Oct-Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
In North Delta	W AN	Jan-Mar	0	1	2	5	11	0	1	2	4	12	0	1	2	3	10	0	1	2	4	10
		Apr-Jun	1	5	14	19	34	1	5	11	19	38	1	5	11	18	43	1	5	11	18	44
		Jul-Sep	1	2	2	3	8	1	2	2	4	6	1	2	3	4	6	1	2	3	3	7
		Oct-Dec	0	2	3	6	38	1	2	3	5	37	2	2	3	5	33	1	3	4	5	43
	C D BN	Jan-Mar	0	6	10	21	29	0	5	9	21	29	1	5	9	15	31	1	5	10	22	34
		Apr-Jun	0	11	19	26	35	0	11	19	26	35	0	0	15	28	42	0	0	16	28	41
		Jul-Sep	0	0	4	12	46	0	0	3	10	46	0	1	5	14	29	0	0	5	16	47
		Oct-Dec	1	3	7	15	33	2	3	5	12	41	2	3	5	11	22	2	4	6	13	25
In South Delta	W AN	Jan-Mar	0	2	5	7	11	0	2	5	8	11	0	1	5	6	10	0	2	5	7	10
		Apr-Jun	1	8	14	19	36	1	7	13	19	33	1	9	12	16	28	1	8	13	17	28
		Jul-Sep	3	6	7	8	15	3	6	7	9	18	5	6	8	9	14	4	6	7	8	9
		Oct-Dec	2	7	8	17	38	2	6	8	16	37	2	5	5	12	49	2	5	6	11	46
	C D BN	Jan-Mar	1	6	9	13	29	1	6	8	15	19	3	8	13	19	27	2	6	12	19	49
		Apr-Jun	6	13	20	34	44	1	13	20	36	43	1	14	19	47	56	1	14	19	44	57
		Jul-Sep	2	9	14	22	50	2	11	21	25	54	0	10	16	27	38	0	7	16	30	37
		Oct-Dec	2	6	13	23	46	4	7	14	18	40	4	6	13	29	48	2	6	12	30	55
Exports	W AN	Jan-Mar	9	33	58	81	92	11	37	58	82	93	9	36	55	82	94	9	36	57	81	93
		Apr-Jun	15	33	49	54	70	15	36	50	57	71	20	35	53	62	74	20	35	55	60	74
		Jul-Sep	40	70	82	86	89	40	69	78	85	89	39	71	78	86	89	39	76	82	86	91
		Oct-Dec	16	46	78	87	89	15	59	77	87	90	21	59	79	88	93	12	60	78	88	93
	C D BN	Jan-Mar	33	61	76	83	92	49	61	76	85	91	41	61	76	84	95	7	61	73	83	95
		Apr-Jun	0	13	27	46	56	0	11	28	49	67	0	12	39	55	64	0	17	36	56	64
		Jul-Sep	0	20	30	49	80	0	15	30	51	79	12	38	55	69	78	10	31	50	70	82
		Oct-Dec	24	55	74	83	91	21	60	77	84	91	28	60	72	88	93	20	58	72	87	92
Other Diversions	W AN	Jan-Mar	0	0	0	1	4	0	0	0	0	4	0	0	0	0	4	0	0	0	1	4
		Apr-Jun	0	1	4	9	29	0	1	4	9	28	0	1	4	7	29	0	1	4	7	29
		Jul-Sep	1	5	9	19	37	1	5	9	19	35	1	4	9	13	22	1	5	9	13	30

	Year	Month	Study 6.0					Study 7.0					Study 7.1					Study 8.0				
Name	Types	Range	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
		Oct-Dec	0	1	2	4	17	0	1	2	4	19	0	1	2	3	13	0	1	2	3	13
	C D BN	Jan-Mar	0	1	2	8	18	0	1	2	5	17	0	1	1	3	13	0	1	1	3	14
		Apr-Jun	2	14	24	45	71	3	13	23	45	71	5	9	14	30	61	5	9	16	33	66
		Jul-Sep	5	19	42	58	98	5	19	41	57	98	4	13	22	30	65	3	12	22	31	65
		Oct-Dec	2	2	4	6	19	2	2	4	7	24	1	1	3	4	11	1	2	3	5	12

Table 9-21. Percent particle fate percentiles after 21 days for particle injection at node 249.

	Year	Month	Study 6.0					Study 7.0					Study 7.1					Study 8.0				
Name	Types	Range	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Past Chipps	W AN	Jan-Mar	0	28	94	99	100	0	28	94	99	100	0	24	95	99	100	0	24	94	99	100
		Apr-Jun	0	10	30	91	100	0	10	29	88	100	0	11	23	91	100	0	8	19	90	100
		Jul-Sep	0	0	0	0	88	0	0	0	0	93	0	0	0	0	93	0	0	0	0	93
		Oct-Dec	0	0	0	3	100	0	0	0	3	100	0	0	0	5	100	0	0	0	4	100
	C D BN	Jan-Mar	0	0	0	1	25	0	0	0	0	17	0	0	0	0	34	0	0	0	0	31
		Apr-Jun	0	0	0	0	24	0	0	0	0	15	0	0	0	0	18	0	0	0	0	15
		Jul-Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Oct-Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
In North Delta	W AN	Jan-Mar	0	0	2	7	27	0	0	2	6	23	0	0	2	5	25	0	0	2	4	24
		Apr-Jun	0	4	28	53	73	0	5	34	55	71	0	4	38	48	64	0	3	39	51	68
		Jul-Sep	1	2	4	8	19	1	3	5	13	24	1	3	6	13	27	1	2	4	13	18
		Oct-Dec	0	3	4	9	47	0	3	6	8	40	0	3	4	9	45	0	2	5	8	53
	C D BN	Jan-Mar	1	4	14	34	72	1	5	16	29	63	2	4	13	27	59	2	4	13	30	75
		Apr-Jun	5	20	47	57	64	4	13	42	56	65	3	16	31	50	62	3	20	31	48	63
		Jul-Sep	1	2	5	11	17	1	2	5	10	33	1	2	5	20	39	1	2	8	21	42
		Oct-Dec	2	6	9	15	42	2	5	7	13	37	2	4	9	13	28	2	4	9	15	44
In South Delta	W AN	Jan-Mar	0	0	2	9	23	0	0	2	9	24	0	0	2	8	22	0	0	2	7	21
		Apr-Jun	0	3	12	19	41	0	3	13	18	40	0	3	16	19	36	0	4	17	20	36
		Jul-Sep	2	4	10	12	20	1	5	9	15	24	1	5	11	14	29	1	5	8	13	23
		Oct-Dec	0	5	7	16	46	0	6	8	12	50	0	4	7	10	47	0	4	7	11	47
	C D BN	Jan-Mar	5	11	21	39	57	5	11	27	44	54	4	12	25	39	52	4	11	24	41	54
		Apr-Jun	15	31	38	45	60	12	32	37	47	61	17	31	42	54	63	17	32	44	55	63
		Jul-Sep	2	5	22	39	53	3	9	17	36	54	3	8	28	47	54	3	7	33	49	56
		Oct-Dec	4	13	19	27	52	4	10	16	24	49	3	9	18	35	48	6	10	16	37	51
Exports	W	Jan-Mar	0	0	1	38	85	0	0	2	41	85	0	0	1	42	88	0	0	2	41	89

Name	Year Types	Month Range	Study 6.0					Study 7.0					Study 7.1					Study 8.0				
			Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
	AN	Apr-Jun	0	0	0	9	36	0	0	1	9	35	0	0	4	15	57	0	0	4	15	62
		Jul-Sep	0	62	74	84	91	0	57	73	81	93	0	58	71	80	89	0	59	79	82	88
		Oct-Dec	0	25	72	87	92	0	18	77	85	94	0	12	79	88	93	0	10	77	88	93
	C D BN	Jan-Mar	0	7	52	80	92	0	15	53	81	92	0	24	53	77	93	0	21	60	81	92
		Apr-Jun	0	0	1	17	54	0	0	3	29	68	0	1	7	23	57	0	1	7	15	59
		Jul-Sep	15	40	61	80	93	0	42	67	81	91	0	28	46	79	88	0	24	41	79	92
		Oct-Dec	12	55	69	79	88	15	61	75	82	89	24	47	73	83	90	3	44	73	82	89
Other Diversions	W AN	Jan-Mar	0	0	0	1	3	0	0	0	1	2	0	0	0	1	2	0	0	1	1	3
		Apr-Jun	0	2	3	5	11	0	2	3	6	12	0	2	3	6	14	0	2	3	6	12
		Jul-Sep	2	5	8	10	15	3	4	8	10	16	3	4	8	12	21	3	5	8	12	16
		Oct-Dec	0	1	2	3	5	0	1	2	3	4	0	2	2	2	4	0	1	2	3	4
	C D BN	Jan-Mar	1	1	2	2	4	1	1	2	2	4	1	1	2	3	5	1	1	2	2	6
		Apr-Jun	3	4	5	16	21	3	4	6	15	21	3	5	6	17	23	3	5	6	16	21
		Jul-Sep	2	6	10	15	23	2	6	10	15	25	3	8	10	17	25	3	6	10	16	25
		Oct-Dec	2	2	3	3	5	2	2	3	3	6	1	2	3	3	7	2	2	3	4	6

Table 9-22. Percent particle fate percentiles after 21 days for particle injection at node 350.

Name	Year Types	Month Range	Study 6.0					Study 7.0					Study 7.1					Study 8.0				
			Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Past Chipps	W AN	Jan-Mar	84	100	100	100	100	85	100	100	100	100	79	100	100	100	100	77	100	100	100	100
		Apr-Jun	55	93	99	100	100	45	94	99	100	100	51	91	98	100	100	51	89	98	100	100
		Jul-Sep	19	26	45	59	99	16	25	47	59	99	18	26	38	62	99	19	25	39	66	100
		Oct-Dec	12	34	74	98	100	22	32	73	99	100	10	34	66	98	100	8	37	64	98	100
	C D BN	Jan-Mar	25	60	71	85	100	38	62	73	86	100	40	64	77	86	100	42	64	76	86	100
		Apr-Jun	8	28	48	66	99	10	29	50	68	97	9	29	49	64	96	7	32	48	64	96
		Jul-Sep	7	21	25	30	43	5	18	22	29	44	6	18	22	28	45	5	18	23	29	54
		Oct-Dec	21	28	39	49	91	17	31	40	50	90	13	26	32	45	89	14	27	34	43	90
In North Delta	W AN	Jan-Mar	0	0	0	0	12	0	0	0	0	10	0	0	0	0	13	0	0	0	0	16
		Apr-Jun	0	0	0	5	39	0	0	1	4	50	0	0	2	7	41	0	0	2	9	41
		Jul-Sep	0	29	43	51	65	0	29	43	54	66	0	29	46	55	65	0	24	44	52	63
		Oct-Dec	0	1	19	52	78	0	1	19	51	72	0	1	22	50	83	0	1	23	50	84
	C D BN	Jan-Mar	0	8	23	34	72	0	9	18	33	55	0	9	18	30	56	0	10	19	31	53
		Apr-Jun	1	30	44	64	82	2	29	45	62	83	3	29	45	64	85	3	29	43	62	84
		Jul-Sep	34	46	57	67	83	37	50	59	66	85	35	50	62	70	86	27	52	60	70	86

Name	Year Types	Month Range	Study 6.0					Study 7.0					Study 7.1					Study 8.0				
			Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
		Oct-Dec	5	39	52	60	72	4	37	50	54	73	5	41	53	57	77	5	43	50	58	77
In South Delta	W AN	Jan-Mar	0	0	0	0	2	0	0	0	0	3	0	0	0	0	3	0	0	0	0	3
		Apr-Jun	0	0	0	0	2	0	0	0	0	2	0	0	0	0	4	0	0	0	0	3
		Jul-Sep	0	2	6	10	12	0	1	7	9	14	0	2	7	11	15	0	2	8	11	13
		Oct-Dec	0	0	4	8	11	0	0	3	7	12	0	0	5	10	13	0	0	6	10	13
	C D BN	Jan-Mar	0	1	3	5	9	0	1	2	5	9	0	2	3	5	11	0	1	2	5	11
		Apr-Jun	0	2	4	5	9	0	2	4	6	9	0	3	4	6	9	0	3	4	6	9
		Jul-Sep	5	9	10	11	13	6	8	11	11	16	4	7	9	12	14	5	6	8	11	13
		Oct-Dec	2	5	6	9	13	1	5	7	9	15	2	6	8	10	16	2	6	8	11	17
Exports	W AN	Jan-Mar	0	0	0	0	2	0	0	0	0	3	0	0	0	0	5	0	0	0	0	5
		Apr-Jun	0	0	0	0	1	0	0	0	0	1	0	0	0	0	3	0	0	0	0	2
		Jul-Sep	0	3	5	7	17	0	2	5	7	11	0	2	5	7	11	0	2	7	9	16
		Oct-Dec	0	0	3	5	9	0	0	3	6	8	0	0	4	7	14	0	0	4	6	14
	C D BN	Jan-Mar	0	0	1	5	8	0	0	1	2	9	0	1	1	3	8	0	1	1	3	12
		Apr-Jun	0	0	0	1	4	0	0	0	2	3	0	0	0	1	4	0	0	0	1	4
		Jul-Sep	1	2	4	10	20	0	2	5	8	19	0	1	3	9	17	0	1	3	11	19
		Oct-Dec	0	2	4	5	8	1	3	4	5	8	1	2	5	7	10	0	2	5	7	9
Other Diversions	W AN	Jan-Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Apr-Jun	0	0	0	1	3	0	0	0	1	3	0	0	0	1	2	0	0	0	1	2
		Jul-Sep	0	1	2	2	3	0	1	2	2	3	0	1	2	2	4	0	1	2	2	3
		Oct-Dec	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1
	C D BN	Jan-Mar	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1
		Apr-Jun	0	1	1	2	4	0	1	1	2	3	0	1	1	2	4	0	1	1	2	3
		Jul-Sep	1	1	2	3	4	0	1	2	3	4	1	1	2	3	4	1	1	2	3	4
		Oct-Dec	0	0	0	0	1	0	0	0	1	1	0	0	0	1	1	0	0	0	1	1

Temperature Results

Simulated temperature results for Study 7.0, Study 7.1, and Study 8.0 are located in Chapter 10, Upstream Effects and in Appendices I and K. The treatment of the Feather River Temperature modeling is different than the other reaches previously mentioned is presented in Appendix K and described below

The Oroville Facilities Relicensing Draft Environmental Impact Report (DEIR) and Biological Assessment (BA) included evaluation of modeling output for three alternatives: the Existing Conditions, the No Project, and the Proposed Project. Operations under OCAP Study 7.0 include the same flow and water temperature requirements as the Existing Conditions Alternative. The Proposed Project simulation utilized flow requirements and water temperature targets from the March 2006 Settlement Agreement for Licensing of the Oroville Facilities (Settlement Agreement), as evaluated in OCAP Study 7.1. While simulated storage conditions in Oroville Reservoir might be different under the 2008 OCAP BA, temperature management actions would follow the same procedures as the Proposed Project. Simulated operations for the 2008 OCAP BA would be able to utilize temperature management actions not exhausted in simulation of the Proposed Project.

The primary difference with regards to water temperature between OCAP Study 7.1 and 8.0 would be the construction of a facility modification to improve DWR’s ability to manage Feather River water temperatures. However, the specific configuration of a facility modification will be examined in a separate environmental process, so no water temperature modeling of a facility modification has been completed. While none of the previously conducted water temperature modeling is directly applicable to OCAP Study 8.0, because the respective flow requirements and water temperature objectives are the same, conditions at the Feather River Fish Hatchery and Robinson Riffle would also be expected to be similar.

Salmon Mortality, Population, and Life Cycle Results

Simulated salmon fishery results are discussed in Chapter 11: Upstream Effects and in Appendices M, O, and Q.

Climate Change Results

CalSim-II long-term average (1922-2003) and dry period average (1929-1934) climate change results are reported in Table 9-23. Appendix R discusses the results of the climate change and sea level rise sensitivity evaluation. The Base Model is the future condition, Study 8.0, simulating the D1641 step. The studies examined include:

1. **Study 9.0 Base Without 1 ft Sea Level Change**: Base Model without the 1 foot sea level rise and 4 inch increase in tidal amplitude
2. **Study 9.1 Base With 1 ft Sea Level Change:** Base Model with 1 foot sea level rise and 4 inch increase in tidal amplitude
3. **Study 9.2 Wetter, Less Warming**: Same assumptions as Study 9.1 hydrology inputs modified for a wetter, less warming climate

4. **Study 9.3 Wetter, More Warming**: Same assumptions as Study 9.1 with hydrology inputs modified for a wetter , more warming climate
5. **Study 9.4 Drier, Less Warming**: Same assumptions as Study 9.1 with hydrology inputs modified for a drier, less warming climate
6. **Study 9.5 Drier, More Warming**: Same assumptions as Study 9.1with hydrology inputs modified for a drier, more warming climate

Table 9-23. Climate Change and Sea Level Rise Long-term Averages and 28-34 Averages

	Study 9.0 Base Without 1' Sea Level Change		Study 9.1 Base With 1' Sea Level Change		Study 9.2 Wetter, Less Warming		Study 9.3 Wetter, More Warming		Study 9.4 Drier, Less Warming		Study 9.5 Drier, More Warming	
End of Sep Storages (TAF)	1922-94	1929-34	1922-94	1929-34	1922-94	1929-34	1922-94	1929-34	1922-94	1929-34	1922-94	1929-34
Trinity	1394	728	1325	642	1524	937	1387	838	1313	607	1120	440
Shasta	2709	1533	2591	1211	2906	2163	2686	1843	2525	1043	2286	835
Oroville	1973	1206	1891	981	2290	1629	1929	1365	1538	885	1474	892
Folsom	492	395	476	369	518	448	472	417	428	300	402	249
New Melones	1533	1043	1533	1045	1695	1304	1594	1190	1022	289	1254	536
CVP San Luis	237	322	209	215	234	228	195	257	154	115	179	162
SWP San Luis	406	296	368	291	483	333	344	265	279	147	257	191
Total San Luis	643	618	576	506	716	561	539	521	433	262	436	352
River Flows (cfs)												
Trinity Release	974	566	958	566	1142	585	1131	585	978	585	874	528
Keswick Release	8674	5430	8693	5513	10049	6159	9967	6020	8907	5617	8019	5160
Nimbus Release	3321	1751	3327	1743	4221	2203	4139	2137	2518	1301	2581	1350
Flow Below Thermalito	4384	2269	4396	2286	5731	2926	5734	2866	3454	1836	3431	1860
Goodwin Release	654	366	654	365	976	387	826	371	389	331	451	354
Flow at Vernalis	4162	1862	4161	1861	5338	1992	4626	1913	3086	1790	3437	1812
Delta Parameters												
SWP Banks (cfs)	4669	2612	4450	2325	4940	3031	4726	2951	4029	2017	3977	2134
CVP Banks (cfs)	108	21	101	14	93	28	107	16	96	8	85	4
Jones (cfs)	3510	2126	3334	1991	3628	2448	3479	2208	3237	1933	3030	1753
Total Banks (cfs)	4777	2634	4551	2338	5034	3060	4834	2967	4124	2026	4062	2137
Cross Valley Pumping (cfs)	108	21	101	14	93	28	107	16	96	8	85	4
Sac Flow at Freeport (cfs)	22303	11281	22488	11541	25474	13114	24685	12933	20956	11072	19900	10950
Excess Outflow (cfs)	14175	1169	15105	1912	20331	2346	19608	2406	11876	1842	11479	1766
Required Outflow (cfs)	6193	5908	5790	5849	5300	6014	5460	6003	6220	5705	6058	5755
Total Inflow (cfs)	30190	13605	30313	13861	35833	15649	34918	15363	26980	13266	26151	13176

Old&Middle River (cfs)	-5151	-3265	-4785	-2874	-4812	-3873	-4906	-3615	-4931	-2576	-4481	-2501
QWEST (cfs)	1378	26	1843	533	2883	-120	2381	74	815	664	1300	731
Deliveries (TAF)												
CVP												
North of Delta												
Agriculture	240	44	221	28	269	73	238	33	201	17	176	8
Settlement Contracts	1857	1735	1857	1735	1879	1899	1879	1899	1864	1794	1825	1616
M&I	201	147	196	138	207	158	200	140	188	127	181	126
Refuge	90	78	90	78	92	89	92	89	91	82	88	69
Total	2388	2005	2364	1980	2447	2219	2409	2161	2345	2019	2270	1818
South of Delta												
Agriculture	1210	224	1097	143	1322	361	1190	166	995	83	889	40
Exchange	852	741	852	741	867	840	867	841	856	774	834	707
M&I	129	92	123	85	132	94	126	86	119	79	115	77
Refuge	273	234	268	226	274	245	273	261	269	226	262	211
Total**	2647	1474	2520	1377	2776	1721	2637	1538	2419	1343	2279	1216
SWP												
Allocation	3209	1484	3085	1377	3332	2032	3312	1954	2772	1280	2739	1337
Table A	2959	1414	2845	1309	3072	1938	3050	1846	2563	1213	2534	1270
Article 56	110	38	112	36	106	47	120	72	111	3	107	34
Article 21	284	309	237	189	371	159	223	130	200	113	195	76
Table A + Art 56	3069	1452	2957	1344	3178	1985	3170	1917	2674	1217	2641	1304
Table A + Art 56 + Art 21	3353	1761	3193	1534	3550	2144	3392	2047	2874	1330	2836	1380
Anticipated Carryover	177	4	167	2	185	28	186	42	137	1	134	1
Allocations (%)												
CVP Allocation												
North of Delta												
Agriculture	68%	20%	63%	16%	76%	29%	68%	17%	57%	13%	50%	8%
M&I	88%	66%	86%	61%	92%	72%	88%	63%	83%	59%	79%	56%
South of Delta												
Agriculture	67%	20%	61%	16%	74%	29%	67%	17%	55%	13%	49%	8%
M&I	88%	66%	86%	61%	91%	72%	88%	63%	83%	59%	79%	56%
SWP												
All SWC	78%	36%	73%	33%	79%	48%	78%	46%	65%	30%	65%	32%

The DSM2-Hydro climate change analysis was run from Water Year 1976 to 1991 and output was provided for a number of locations in the Delta. The boundary tide incorporated a one-foot and four-inch (10% increase) amplitude adjustment for sea-level rise which was consistent with the ANN used in CalSim-II. Figure 9-29 shows a map of the Delta and all of the available output locations as well as the direction of positive flow and velocity for each location. Table 9-15 lists these output locations along with the common name, representative DSM2 channel number and distance in channel. All of the results from DSM2-Hydro are provided in spreadsheets, but for purposes of this document and Appendix G only four sites were selected for discussion. These four sites were generally a combination of flows that represent an imaginary boundary internal to the Delta. These four sites were:

- **Cross Delta flow –** a combination of Georgiana Slough, North Fork of Mokelumne, and South Fork of the Mokelumne (GEORGIANA_SL, NORTH_FORK_MOKE, and RSMKL008 as respectively labeled in Figure 9-29).
- **QWest flow –** a combination of San Joaquin River at Blind Point, Three Mile Slough, and Dutch Slough (RSAN014,SLTRM004, and SLDUT007 as respectively labeled in Figure 9-29).
- **Old and Middle River flow –** a combination of Old River at Bacon Island and Middle River at Middle River (ROLD024, and RMID015 as respectively labeled in Figure 9-29).
- **Old River at Head –** described by a single output location ROLD074 as labeled in Figure 9-29.

One location from each of the groups was used to give an indication of the average velocity. From the Cross Delta group GEORGIANA_SL is presented for velocity. From the Qwest group RANS014 is presented for velocity, and from Old and Middle River RMID015 is presented.

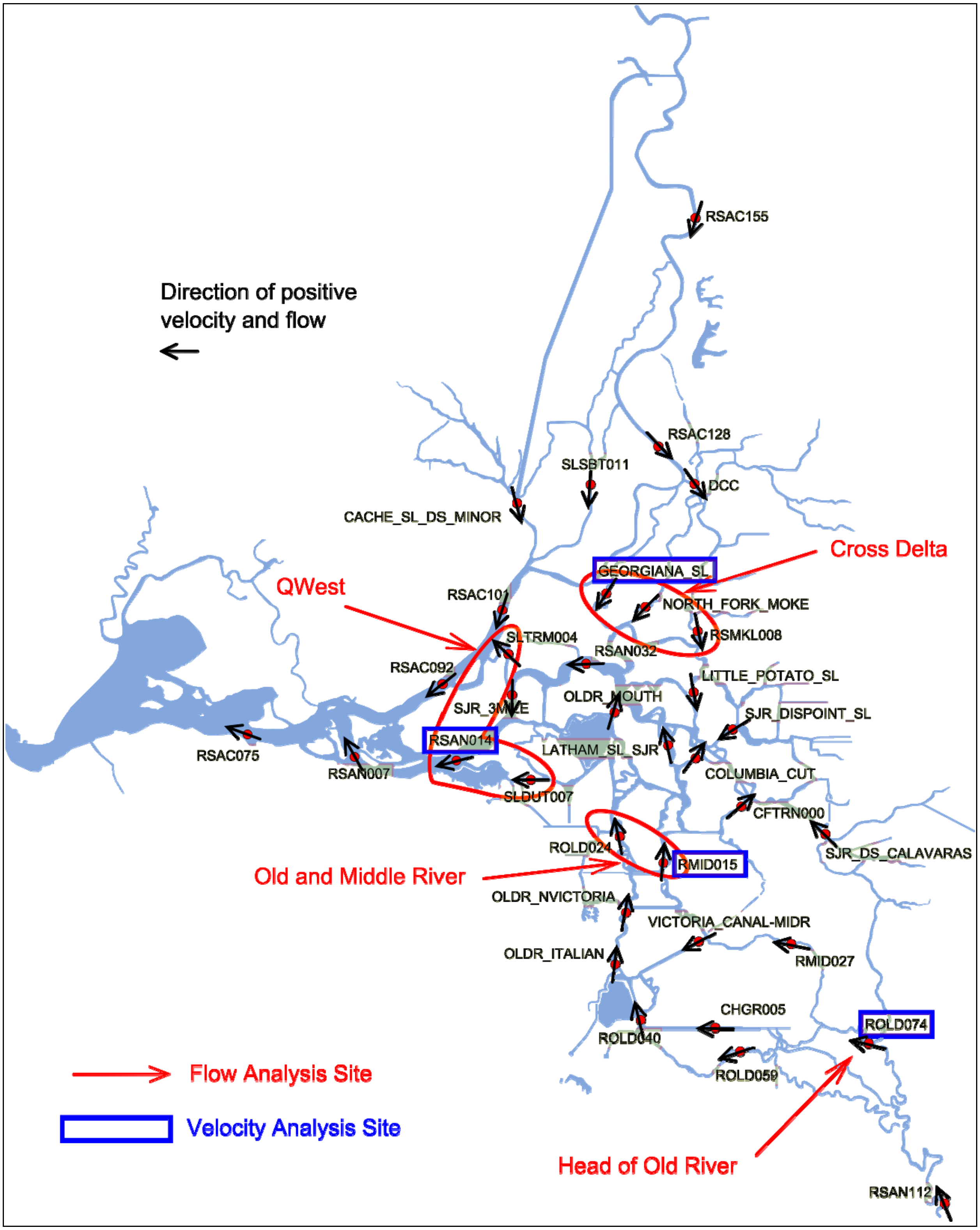

Figure 9-31. DSM2-Hydro locations of output for flow (cfs) and velocity (ft/s). Arrows represent the direction of positive flow and velocity.

Table 9-24. Definitions for the DSM2 output

DSM2 Output Name	Channel	Distance	Common Name
CFTRN000	172	727	Turner Cut
CHGRL005	211	1585	Grant Line Canal (West Position)
RMID015	144 - 145	838	Middle River at Middle River (west channel)
RMID027	133	3641	Middle River at Tracy Blvd
ROLD014	117	0	Old River at Holland Cut
ROLD024	106	2718	Old River at Bacon Island
ROLD040	82	2609	Old River at Clifton Court Ferry
ROLD059	71	3116	Old River at Tracy Road
ROLD074	54	735	Head of Old River
RSAC075	437	11108	Sacramento River at Mallard Island
RSAC092	434	435	Sacramento River at Emmaton
RSAC101	430	9684	Sacramento River at Rio Vista
RSAC128	421	8585	Sacramento River above Delta Cross Channel
RSAC155	414	11921	Sacramento River at Freeport
RSAN007	52	366	San Joaquin River at Antioch
RSAN014	49	9570	San Joaquin River at Blind Point
RSAN024	47	8246	San Joaquin River at Bradford Isl.
RSAN032	349	9672	San Joaquin River at San Andreas Landing
RSAN058	20	2520	San Joaquin River at Stockton Ship Channel
RSAN112	17	4744	San Joaquin River at Vernalis
RSMKL008	344	7088	South Fork Mokelumne at Staten Island
SLDUT007	274	7351	Dutch Slough
SLSBT011	385	2273	Steamboat Slough
SLTRM004	310	540	Three Mile Slough
DCC	365	0	Delta Cross Channel
COLUMBIA_CUT	160	50	Columbia Cut
SJR_DS_CALAVARAS	21	0	San Joaquin River downstream Calaveras River
SJR_3MILE	49	9570	San Joaquin River at Three Mile Slough

DSM2 Output Name	**Channel**	**Distance**	**Common Name**
OLDR_ITALIAN	88	0	Old River at Italian Slough
OLDR_NVICTORIA	91	4119	Old River at North Victoria Canal
OLDR_MOUTH	124	7062	Mouth of Old River
LATHAM_SL_SJR	161	10808	Latham Slough at San Joaquin River
VICTORIA_CANAL_MIDR	226	4153	Victoria Canal at Middle River
SJR_DISPOINT_SL	314	8130	Disappointment Slough at San Joaquin River
LITTLE_POTATO_SL	325	9962	Little Potato Slough
NORTH_FORK_MOKE	363	6133	North Fork Mokelumne River
GEORGIANA_SL	371	7766	Georgiana Slough
CACHE_SL_DS_MINOR	398	0	Cache Slough downstream Minor Slough
OMR	144 - 145 + 106	--	Old and Middle River
QWEST	274 + 49 + 310	--	Western Flow (QWEST)
XDELTA	371 + 363 + 344	--	Cross Delta Flow

The DSM2-Hydro results were aggregated from a fifteen-minute time-step to a daily average. A Godin filter was first applied to the data to remove the tidal variations, and then a daily average of the filtered data was applied. This is the same process that the USGS uses to determine daily averages for locations under tidal influence.

The flow results for the more warming case are presented in Table 9-25 and the less warming case results are presented in Table 9-26. The velocity results for the more warming case are presented in Table 9-27 and the less warming case results are presented in Table 9-28 The tables present the minimum, twenty five percentile, median, seventy five percentile, and maximum value for water-years 1976 to 1991, broken down into groups representing annual quarters, and year type groups. The monthly output was grouped into the annual quarters: January through March (Jan-Mar), April through June (Apr-Jun), July through September (Jul-Sep), and October through December (Oct-Dec). The year types were grouped into two representative groups: Wet and Above Normal (W-AN), and Below Normal, Dry and Critical (C-D-BN). For regional flows that cross more than one individual location, for example Old and Middle River includes two output locations, a simple time period summation was conducted.

Table 9-25. DSM2-Hydro tidally filtered daily average flow for water-years 1976 to 1991. Shading indicates negative (landward) flows. Positive flows are towards the ocean.

Name	Year Types	Month Range	Base					Wetter, Less Warming					Wetter, More Warming				
			Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Head of Old River	W AN	Jan-Mar	1349	3722	8039	9468	16708	1408	5568	8701	10567	17974	1350	4932	8627	11291	18550
		Apr-Jun	0	3685	5707	8645	11252	0	5068	7442	9164	12909	0	2157	4167	8547	11885
		Jul-Sep	449	1889	2102	3978	9682	440	2239	3063	4963	12213	406	1743	2012	3010	8612
		Oct-Dec	112	313	822	1612	9549	112	322	1144	5461	13201	112	321	752	1664	11307
	C D BN	Jan-Mar	578	1021	1367	1683	4575	637	1057	1370	1779	6363	637	1093	1376	1742	7728
		Apr-Jun	0	0	606	1133	4163	0	0	735	1202	5474	0	0	673	1171	4027
		Jul-Sep	214	314	384	449	1244	202	329	389	491	1931	190	314	391	463	1444
		Oct-Dec	131	257	408	1042	1612	160	265	433	1059	2227	155	260	399	1058	1861
Old and Middle River	W AN	Jan-Mar	-10896	-6733	-3180	5100	22138	-10321	-5610	94	7920	24229	-10340	-5744	-555	8693	25160
		Apr-Jun	-9316	-5840	-4015	-693	12606	-9394	-5124	-3347	1183	14326	-8525	-5525	-3182	-925	14585
		Jul-Sep	-11350	-8709	-7526	-6793	3258	-11723	-8291	-7259	-6022	9579	-9463	-7967	-7270	-6540	-1793
		Oct-Dec	-11595	-9764	-7528	-4080	6749	-11595	-9561	-8094	-3879	15507	-11595	-9725	-8293	-4043	11925
	C D BN	Jan-Mar	-11345	-8206	-5811	-3671	766	-11344	-7636	-5925	-3313	-267	-11344	-8612	-6377	-4186	-372
		Apr-Jun	-9490	-4555	-2439	-1865	-555	-8275	-4719	-3137	-2149	-482	-9102	-5222	-2912	-1964	-234
		Jul-Sep	-11959	-8619	-5276	-4092	-1132	-12339	-8325	-6258	-3939	-882	-11746	-7731	-5990	-4286	-583
		Oct-Dec	-11213	-7839	-6565	-4660	-326	-11502	-10118	-8299	-5212	-1687	-11222	-8547	-7055	-4796	-392
QWEST	W AN	Jan-Mar	-6574	6496	17895	33459	71816	-6552	9410	21975	38206	77058	-6825	12946	21760	41638	78955
		Apr-Jun	-4603	3672	6819	16307	46694	-4285	5299	9846	20458	50574	-4590	3932	6708	14821	51392
		Jul-Sep	-5226	-1140	405	3421	26442	-5381	75	1798	4390	34053	-3994	-854	740	2673	17883
		Oct-Dec	-11968	-891	1475	5921	43199	-10791	-799	1977	9127	63503	-11237	-1304	937	5810	54501
	C D BN	Jan-Mar	-11554	-2331	-21	2332	11441	-10823	-1957	446	2448	18108	-11338	-2575	-18	2020	17987
		Apr-Jun	-7833	76	1634	3345	8902	-7116	114	1897	3676	8515	-7555	-148	1572	3302	8560
		Jul-Sep	-6955	-1600	-162	1138	6148	-6900	-1514	-227	1297	5034	-6431	-1301	-172	1242	5178
		Oct-Dec	-11923	-1707	178	2028	7002	-12037	-2247	-264	1648	5767	-11785	-1774	195	1839	6789
Cross Delta	W AN	Jan-Mar	4630	8704	13143	16306	23616	5342	9527	14193	16979	25965	5109	10864	15158	17440	29161
		Apr-Jun	3296	4427	6497	9757	18349	3381	4856	6112	9872	19128	3213	4078	7323	8956	18829
		Jul-Sep	5464	6448	7066	8611	11596	5200	6164	6881	7574	10475	5069	5972	6430	8492	10444
		Oct-Dec	2159	5448	7331	9106	17428	2185	5365	7391	9714	22800	2171	5157	6916	8717	20272
	C D BN	Jan-Mar	2174	3284	4108	5804	10507	2151	3324	4448	6250	13008	2134	3468	4456	6408	12933
		Apr-Jun	1458	2596	3572	4778	9422	1549	2767	3530	5297	9345	1521	2816	3543	4912	9823
		Jul-Sep	3644	4876	5638	7571	9210	2556	4991	5867	7219	9642	2830	4962	5613	7346	9443
		Oct-Dec	1875	4006	5376	6448	9609	2193	4630	6176	7048	10088	2113	4374	5540	6908	10413

Table 9-26. DSM2-Hydro tidally filtered daily average flow for water-years 1976 to 1991. Shading indicates negative (landward) flows. Positive flows are towards the ocean.

Name	Year Types	Month Range	Base					Drier, Less Warming					Drier, More Warming				
			Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Head of Old River	W AN	Jan-Mar	1349	3722	8039	9468	16708	1348	2951	4495	7080	14338	1347	3228	5323	8823	18182
		Apr-Jun	0	3685	5707	8645	11252	0	1608	2432	6105	10492	0	2040	2762	6707	11622
		Jul-Sep	449	1889	2102	3978	9682	395	491	1849	2258	5630	402	511	1927	2504	5968
		Oct-Dec	112	313	822	1612	9549	112	284	522	1557	8693	111	275	700	1610	9008
	C D BN	Jan-Mar	578	1021	1367	1683	4575	661	1023	1298	1531	3148	584	1016	1310	1544	3434
		Apr-Jun	0	0	606	1133	4163	0	0	524	1018	2199	0	0	522	967	2904
		Jul-Sep	214	314	384	449	1244	186	294	350	414	1115	202	293	355	417	1182
		Oct-Dec	131	257	408	1042	1612	131	254	375	923	1629	106	249	381	870	1620
Old and Middle River	W AN	Jan-Mar	-10896	-6733	-3180	5100	22138	-11017	-8454	-6368	-1875	18085	-11018	-8363	-4360	1616	24586
		Apr-Jun	-9316	-5840	-4015	-693	12606	-8838	-5660	-4458	-2545	10193	-7793	-4734	-3673	-1624	13746
		Jul-Sep	-11350	-8709	-7526	-6793	3258	-10959	-9488	-8476	-7403	-4947	-11093	-8490	-7520	-6514	-3975
		Oct-Dec	-11595	-9764	-7528	-4080	6749	-11592	-9570	-7090	-4364	2692	-11595	-9522	-5789	-3140	3915
	C D BN	Jan-Mar	-11345	-8206	-5811	-3671	766	-11344	-8295	-6270	-2114	-17	-11343	-7309	-5451	-2400	-105
		Apr-Jun	-9490	-4555	-2439	-1865	-555	-8619	-3452	-2311	-1745	-560	-7367	-2563	-2032	-1577	-555
		Jul-Sep	-11959	-8619	-5276	-4092	-1132	-10322	-6409	-4499	-3466	-1024	-10853	-5711	-4275	-3371	-1383
		Oct-Dec	-11213	-7839	-6565	-4660	-326	-11253	-8462	-6418	-3810	341	-11236	-7928	-5776	-2900	336
QWEST	W AN	Jan-Mar	-6574	6496	17895	33459	71816	-6915	4733	11456	18506	62135	-7296	5480	13635	25127	76519
		Apr-Jun	-4603	3672	6819	16307	46694	-4790	2288	4982	9346	40762	-3972	3069	5662	9170	47956
		Jul-Sep	-5226	-1140	405	3421	26442	-5262	-1652	-326	1341	10976	-5058	-1129	273	2005	8864
		Oct-Dec	-11968	-891	1475	5921	43199	-10970	-665	1209	4478	34664	-11951	-554	1666	5473	36036
	C D BN	Jan-Mar	-11554	-2331	-21	2332	11441	-11914	-2393	9	1962	9714	-11955	-1903	74	2267	7714
		Apr-Jun	-7833	76	1634	3345	8902	-7198	395	1919	3586	9258	-6221	817	2258	3763	8593
		Jul-Sep	-6955	-1600	-162	1138	6148	-6752	-748	500	1905	6150	-5355	-491	612	1892	5690
		Oct-Dec	-11923	-1707	178	2028	7002	-10344	-1661	490	2551	7737	-9683	-1264	851	2905	10217
Cross Delta	W AN	Jan-Mar	4630	8704	13143	16306	23616	4359	8008	12013	14968	21386	3982	7498	10903	15635	21323
		Apr-Jun	3296	4427	6497	9757	18349	3201	3957	5936	9104	16566	2960	3675	6023	7769	17482
		Jul-Sep	5464	6448	7066	8611	11596	4946	6737	7867	8461	11306	4760	6153	6802	7962	11315
		Oct-Dec	2159	5448	7331	9106	17428	2133	4952	6971	9333	15201	2159	5191	6362	8663	14828
	C D BN	Jan-Mar	2174	3284	4108	5804	10507	1872	3021	3780	4975	10435	1786	3046	3708	4974	10477
		Apr-Jun	1458	2596	3572	4778	9422	1580	2460	3152	4962	8666	1503	2409	3032	5003	7445
		Jul-Sep	3644	4876	5638	7571	9210	3320	4669	5294	5867	8206	3223	4396	5009	5792	9001
		Oct-Dec	1875	4006	5376	6448	9609	1897	3922	5139	6578	9303	1830	3858	5025	6128	9922

Table 9-27. DSM2-Hydro tidally filtered daily average velocity for water-years 1976 to 1991. Shading indicates negative (landward) velocities. Positive velocities are towards the ocean.

	Year	Month			Base					Wetter, Less Warming					Wetter, More Warming		
Name	Types	Range	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Head of Old River	W AN	Jan-Mar	0.76	1.63	2.48	2.54	3.17	0.79	2.04	2.52	2.59	3.28	0.76	1.90	2.54	2.67	3.33
		Apr-Jun	0.00	1.63	2.10	2.53	2.67	0.00	1.96	2.42	2.57	2.86	0.00	1.08	1.77	2.54	2.71
		Jul-Sep	0.26	0.97	1.06	1.67	2.60	0.25	1.09	1.42	1.91	2.78	0.23	0.90	1.03	1.42	2.56
		Oct-Dec	0.07	0.19	0.46	0.86	2.60	0.07	0.19	0.61	2.03	2.87	0.07	0.19	0.43	0.89	2.69
	C D BN	Jan-Mar	0.32	0.55	0.74	0.89	1.84	0.37	0.59	0.74	0.94	2.23	0.37	0.61	0.75	0.92	2.47
		Apr-Jun	0.00	0.00	0.35	0.64	1.75	0.00	0.00	0.42	0.66	2.07	0.00	0.00	0.39	0.64	1.68
		Jul-Sep	0.12	0.18	0.23	0.27	0.72	0.11	0.19	0.23	0.29	1.02	0.11	0.18	0.23	0.27	0.84
		Oct-Dec	0.08	0.15	0.24	0.57	0.87	0.09	0.16	0.26	0.59	1.14	0.09	0.15	0.24	0.59	0.99
Middle River at Middle River	W AN	Jan-Mar	-0.27	-0.16	-0.08	0.13	0.51	-0.27	-0.14	0.01	0.20	0.55	-0.27	-0.14	-0.01	0.21	0.58
		Apr-Jun	-0.23	-0.15	-0.10	-0.01	0.31	-0.24	-0.12	-0.08	0.04	0.35	-0.21	-0.14	-0.07	-0.01	0.35
		Jul-Sep	-0.29	-0.22	-0.18	-0.16	0.09	-0.30	-0.21	-0.18	-0.14	0.25	-0.23	-0.20	-0.18	-0.16	-0.04
		Oct-Dec	-0.29	-0.25	-0.19	-0.10	0.17	-0.29	-0.24	-0.20	-0.09	0.38	-0.29	-0.25	-0.21	-0.10	0.29
	C D BN	Jan-Mar	-0.29	-0.21	-0.15	-0.09	0.02	-0.29	-0.19	-0.15	-0.08	0.00	-0.29	-0.22	-0.16	-0.10	0.00
		Apr-Jun	-0.23	-0.11	-0.06	-0.04	-0.01	-0.21	-0.12	-0.08	-0.05	-0.01	-0.22	-0.13	-0.07	-0.05	-0.01
		Jul-Sep	-0.30	-0.22	-0.13	-0.10	-0.02	-0.31	-0.21	-0.15	-0.09	-0.02	-0.30	-0.19	-0.15	-0.10	-0.01
		Oct-Dec	-0.29	-0.20	-0.16	-0.12	-0.01	-0.30	-0.26	-0.21	-0.13	-0.04	-0.29	-0.22	-0.18	-0.12	-0.01
San Joaquin River at Blind Point	W AN	Jan-Mar	-0.01	0.14	0.25	0.41	0.80	0.00	0.18	0.30	0.45	0.86	0.00	0.21	0.29	0.49	0.89
		Apr-Jun	0.03	0.11	0.13	0.23	0.53	0.02	0.12	0.16	0.26	0.57	0.03	0.11	0.13	0.21	0.58
		Jul-Sep	0.00	0.05	0.08	0.10	0.30	0.00	0.07	0.09	0.11	0.38	0.01	0.06	0.08	0.10	0.22
		Oct-Dec	-0.04	0.06	0.09	0.13	0.51	-0.03	0.06	0.09	0.20	0.74	-0.03	0.05	0.08	0.17	0.65
	C D BN	Jan-Mar	-0.05	0.05	0.07	0.10	0.20	-0.03	0.05	0.08	0.10	0.25	-0.05	0.05	0.07	0.10	0.25
		Apr-Jun	0.01	0.07	0.09	0.10	0.17	0.01	0.07	0.09	0.11	0.17	0.01	0.07	0.09	0.10	0.17
		Jul-Sep	-0.01	0.05	0.07	0.08	0.13	-0.01	0.05	0.06	0.08	0.12	-0.01	0.05	0.07	0.08	0.12
		Oct-Dec	-0.05	0.05	0.07	0.09	0.14	-0.06	0.05	0.07	0.08	0.13	-0.05	0.05	0.07	0.08	0.13
Georgiana Slough	W AN	Jan-Mar	0.94	1.84	2.31	2.50	2.64	1.25	1.91	2.43	2.53	2.62	1.19	2.07	2.48	2.54	2.66
		Apr-Jun	0.60	0.88	1.01	1.52	2.60	0.64	0.91	1.07	1.65	2.59	0.68	0.86	0.98	1.59	2.60
		Jul-Sep	0.62	0.74	0.80	0.91	1.31	0.61	0.74	0.80	0.90	1.72	0.57	0.69	0.77	0.91	1.32
		Oct-Dec	0.49	0.75	0.93	1.53	2.65	0.49	0.80	1.16	1.94	2.68	0.49	0.77	0.88	1.65	2.67
	C D BN	Jan-Mar	0.57	0.85	1.00	1.23	2.01	0.57	0.85	1.01	1.40	2.68	0.51	0.87	1.05	1.35	2.68
		Apr-Jun	0.51	0.66	0.84	0.97	1.61	0.54	0.75	0.88	0.98	1.92	0.54	0.77	0.90	0.99	1.94
		Jul-Sep	0.49	0.62	0.69	0.87	1.05	0.43	0.63	0.70	0.84	1.08	0.45	0.62	0.68	0.85	1.05
		Oct-Dec	0.48	0.65	0.74	0.85	1.36	0.51	0.72	0.80	0.98	1.69	0.50	0.67	0.78	0.88	1.42

Table 9-28. DSM2-Hydro tidally filtered daily average velocity for water-years 1976 to 1991. Shading indicates negative (landward) velocities. Positive velocities are towards the ocean.

	Year	Month	Base					Drier, Less Warming					Drier, More Warming				
Name	Types	Range	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Head of Old River	W AN	Jan-Mar	0.76	1.63	2.48	2.54	3.17	0.76	1.35	1.80	2.31	2.96	0.76	1.46	1.99	2.53	3.30
		Apr-Jun	0.00	1.63	2.10	2.53	2.67	0.00	0.86	1.21	2.16	2.62	0.00	1.02	1.33	2.28	2.70
		Jul-Sep	0.26	0.97	1.06	1.67	2.60	0.23	0.29	0.95	1.13	2.04	0.23	0.30	1.00	1.23	2.12
		Oct-Dec	0.07	0.19	0.46	0.86	2.60	0.07	0.17	0.29	0.83	2.57	0.07	0.16	0.40	0.86	2.59
	C D BN	Jan-Mar	0.32	0.55	0.74	0.89	1.84	0.37	0.56	0.71	0.82	1.45	0.33	0.55	0.73	0.82	1.51
		Apr-Jun	0.00	0.00	0.35	0.64	1.75	0.00	0.00	0.30	0.57	1.10	0.00	0.00	0.30	0.54	1.35
		Jul-Sep	0.12	0.18	0.23	0.27	0.72	0.11	0.17	0.20	0.24	0.65	0.12	0.17	0.20	0.24	0.69
		Oct-Dec	0.08	0.15	0.24	0.57	0.87	0.08	0.15	0.22	0.50	0.88	0.06	0.14	0.23	0.47	0.88
Middle River at Middle River	W AN	Jan-Mar	-0.27	-0.16	-0.08	0.13	0.51	-0.28	-0.21	-0.16	-0.04	0.42	-0.28	-0.21	-0.11	0.05	0.56
		Apr-Jun	-0.23	-0.15	-0.10	-0.01	0.31	-0.22	-0.14	-0.11	-0.06	0.25	-0.19	-0.11	-0.09	-0.03	0.34
		Jul-Sep	-0.29	-0.22	-0.18	-0.16	0.09	-0.27	-0.24	-0.21	-0.18	-0.12	-0.28	-0.21	-0.18	-0.16	-0.10
		Oct-Dec	-0.29	-0.25	-0.19	-0.10	0.17	-0.29	-0.24	-0.18	-0.11	0.07	-0.29	-0.24	-0.14	-0.07	0.10
	C D BN	Jan-Mar	-0.29	-0.21	-0.15	-0.09	0.02	-0.29	-0.21	-0.16	-0.05	0.00	-0.29	-0.18	-0.14	-0.06	0.00
		Apr-Jun	-0.23	-0.11	-0.06	-0.04	-0.01	-0.21	-0.08	-0.05	-0.04	-0.01	-0.18	-0.06	-0.05	-0.04	-0.01
		Jul-Sep	-0.30	-0.22	-0.13	-0.10	-0.02	-0.26	-0.16	-0.11	-0.08	-0.02	-0.27	-0.14	-0.10	-0.08	-0.03
		Oct-Dec	-0.29	-0.20	-0.16	-0.12	-0.01	-0.29	-0.22	-0.16	-0.09	0.01	-0.29	-0.20	-0.14	-0.07	0.01
San Joaquin River at Blind Point	W AN	Jan-Mar	-0.01	0.14	0.25	0.41	0.80	-0.01	0.13	0.19	0.28	0.71	-0.02	0.13	0.21	0.33	0.83
		Apr-Jun	0.03	0.11	0.13	0.23	0.53	0.02	0.09	0.12	0.16	0.47	0.03	0.10	0.13	0.16	0.54
		Jul-Sep	0.00	0.05	0.08	0.10	0.30	0.00	0.05	0.07	0.08	0.17	0.00	0.05	0.07	0.09	0.17
		Oct-Dec	-0.04	0.06	0.09	0.13	0.51	-0.03	0.06	0.08	0.11	0.43	-0.04	0.06	0.09	0.12	0.44
	C D BN	Jan-Mar	-0.05	0.05	0.07	0.10	0.20	-0.06	0.05	0.07	0.09	0.16	-0.06	0.05	0.07	0.09	0.16
		Apr-Jun	0.01	0.07	0.09	0.10	0.17	0.01	0.07	0.09	0.10	0.17	0.02	0.08	0.09	0.11	0.17
		Jul-Sep	-0.01	0.05	0.07	0.08	0.13	0.00	0.06	0.07	0.09	0.13	0.01	0.06	0.07	0.09	0.12
		Oct-Dec	-0.05	0.05	0.07	0.09	0.14	-0.04	0.05	0.07	0.09	0.15	-0.01	0.06	0.08	0.09	0.16
Georgiana Slough	W AN	Jan-Mar	0.94	1.84	2.31	2.50	2.64	0.90	1.80	2.21	2.49	2.65	0.87	1.59	2.18	2.46	2.63
		Apr-Jun	0.60	0.88	1.01	1.52	2.60	0.74	0.90	1.04	1.36	2.60	0.70	0.83	0.91	1.24	2.59
		Jul-Sep	0.62	0.74	0.80	0.91	1.31	0.57	0.76	0.85	0.90	1.17	0.56	0.70	0.77	0.87	1.06
		Oct-Dec	0.49	0.75	0.93	1.53	2.65	0.49	0.73	0.85	1.29	2.62	0.49	0.70	0.87	1.48	2.60
	C D BN	Jan-Mar	0.57	0.85	1.00	1.23	2.01	0.45	0.80	0.93	1.18	1.82	0.44	0.79	0.93	1.15	1.84
		Apr-Jun	0.51	0.66	0.84	0.97	1.61	0.55	0.68	0.80	0.90	1.56	0.53	0.68	0.76	0.86	1.54
		Jul-Sep	0.49	0.62	0.69	0.87	1.05	0.46	0.59	0.66	0.72	0.99	0.46	0.58	0.63	0.71	1.01
		Oct-Dec	0.48	0.65	0.74	0.85	1.36	0.49	0.64	0.74	0.84	1.22	0.49	0.62	0.70	0.85	1.25

Model Limitations

The following model limitations are general and highlight key limitations of individual models. This list does not include all limitations associated with the models.

General Modeling Limitations

- The models are good representations of the laws of conservation, but nonetheless include simplifications or estimations of certain processes. For example, temporal and spatial resolution (i.e. monthly time step and geographic representation) is aggregated to simulate a longer period of time rather than a short period of time at a shorter time step for similar levels of effort and computation, and to simplify the spatial extent of the model. Therefore, model uncertainty is inherent in the results.
- Input model data are imperfect. Model parameter error can accumulate such as in this example: river flow data may be plus or minus 5-10%; temperature data and water quality data are subject to instrument resolution, deployment technique and location; geometry data can have considerable effects on temperature due to approximations in surface area depth/cross sectional area; meteorological data is often not local and model domains are sufficiently large that meteorological data can vary notably from one location to another. All input parameters introduce some level of uncertainty.
- The numerical solution to the governing equations included in the models can also introduce error.
- The OCAP BA models are designed to compare and contrast the effect of current and assumed future operational conditions. The models are not predictive; they are not intended to forecast the future (i.e. no forecast data or information are used).

CalSim-II

- The main limitation of CalSim-II model is the time step. Mean monthly flows do not define daily variations that could occur in the rivers from dynamic conditions. However, monthly results are still useful for general comparison of scenarios.
- The CalSim-II model is not a hydraulic model. CalSim-II does not use channel characteristics, such as channel roughness, cross-sectional geometry, etc., to simulate the routing of water as commonly found in other models simulating rainfall runoff response.
- CalSim-II cannot completely capture the policy-oriented operation and coordination the 800,000 af of dedicated CVPIA 3406 (b)(2) water and the CALFED EWA (regular WOMT, B2IT, and EWAT agencies meetings). The CalSim-II model is set up to run each step of the 3406(b)(2) on an annual basis and because the WQCP and Endangered Species Act (ESA) actions are set on a priority basis that can trigger actions using 3406(b)(2) water or EWA assets, the model will exceed at times the dedicated amount of 3406(b)(2) water that is available. Moreover, the 3406(b)(2) and EWA operations in CalSim-II are just one set of plausible actions aggregated to a monthly representation and

modulated by year type. However, they do not fully account for the potential weighing of assets versus cost or the dynamic influence of biological factors on the timing of actions. The monthly time-step of CalSim-II also requires day-weighted monthly averaging to simulate minimum in-stream flow levels, VAMP actions, export reductions, and X2-based operations that occur within a month. This averaging can either under- or over-estimate the amount of water needed for these actions.

- CalSim-II uses simplified rules and guidelines to simulate SWP and CVP delivery allocation. Therefore the results may not reflect how the SWP and CVP would actually operate under extreme hydrologic conditions (very wet or very dry). The allocation process in the modeling is weighted heavily on storage conditions and inflow to the reservoirs that are fed into the curves mentioned previously in the Hydrologic Modeling Methods section and does not project inflow from contributing streams when making an allocation. This curve-based approach does cause some variation in results between studies that would be closer with a more robust approach to the allocation process.
- There are a number of rule-curves embedded in CalSim-II and it is these rule-curves that drive the water balance between the reservoirs, determine how much water to carryover until the following year, and allocate the amount of water for delivery. It is difficult to produce a rule-curve in CalSim-II that produces good realistic results in the full spectrum of year types. CalSim-II rule-curves often produce sub-optimal results with respect to Project operations in the driest years. Some results imply that the projects would operate the reservoirs to unrealistically low levels in these dry year outliers. In reality the Projects could and would operate to higher reservoir elevations in these extremely dry years. An examination of modeling output suggests that this would be possible by reducing project releases and exports to minimums rather than the unrealistic rates often assumed by the models in these years.
- Transfer capacity is calculated by looking at the amount of flow available under the EI ratio and the amount of available capacity at the exports. This gives a very general view of the amount of water that could be transferred. However, to be more complete in the analysis transfers should also take the current salinity profile into account as well. Generally during a transfer, a unit of water will be released somewhere in the system and increase the inflow to the Delta. As that unit of water enters the Delta the exports will increase and a portion of that unit gets exported and the remaining portion goes to support the Delta standards. The portion of the unit that goes to support Delta standards is called “carriage water”. Transfers for OCAP were post-processed and incorporating constraints based on the salinity profile to determine carriage water was not done. So the estimated transfers will be on the high side.

DSM2

- DSM2 is a one-dimensional model. As such, it is only capable of simulating the flow in the longitudinal direction. Any detailed description such as vertical/lateral mixing, changing of the flow patterns due to bends or unusual expansion or contraction of the rivers are not simulated.

- DSM2 simulates reservoirs as constantly mixed reactors and each is essentially only a container that holds water. Any mixing of water in there occurs instantly. Reservoirs are used for five locations in the model: Clifton Court Forebay, Franks Tract, Little Franks Tract, Mildred Island, and Discovery Bay.
- DSM2 uses CalSim-II results for Delta inflows. These inflows are monthly average flows so the model at times may see very steep transitions in flow from month to month. Because of these transitions the hydrodynamic conditions may take a few simulation days to adjust to the new inflows. Given this transition period the results from DSM2-Hydro should not be used during the transitions between months. Therefore all of the PTM simulations were begun 4 days after these transitions, and particle fate collected 3 to 6 days before these transitions. However the hydrodynamic results do include periods up to the transition.
- The Delta Island Consumptive Use (DICU) simulates the agriculture diversions and return flows. The DICU for the model is consistent with the total monthly volume in CalSim-II. Though the DICU for DSM2 is more spatially represented it still assumes a constant monthly flow rate.
- The DSM2-PTM has the ability to use in channel dispersion but in order to run the simulations as quickly as possible only advection was used. This means that rather than using the pseudo three-dimensional velocity profiles to determine the velocity imposed on a particle, a one-dimensional velocity straight from DSM2-Hydro was used. This means that the particles only disperse when moving from channel to channel.

Temperature Models

- The monthly temperature models are unable to accurately simulate certain aspects of the actual operations strategies used when attempting to meet temperature objectives. This is especially true on the upper Sacramento River, and the American River where adjustments can be made for temperature control. The SRWQM and the Feather River models (with shorter time-steps) were applied to compensate for the deficiencies of the monthly model. Elsewhere, the monthly temperature model results may not capture the full range of daily temperature variability. In addition, imperfections in simulated monthly results from CalSim-II reservoir operations can influence cold water pool storage and downstream temperature results. Historical temperature observations are also presented in Appendix U where sub-monthly temperature model results are unavailable for the full period of evaluation.
- There is also uncertainty regarding performance characteristics of the Shasta TCD. Because of the hydraulic characteristics of the TCD, including leakage, overflow, and performance of the side intakes, the typical model releases are cooler than can be achieved in real-time operations; therefore, a more conservative approach is taken in real-time operations that is not fully represented by the models.

Salmon Mortality and Life Cycle Models

- The salmon mortality models (Reclamation salmon mortality model and SALMOD) are limited to temperature effects on early life stages of Chinook salmon. They do not evaluate potential direct or indirect temperature impacts on later life stages, such as emergent fry, smolts, juvenile out-migrants, or adults. Also, they do not consider other factors that may affect salmon mortality, such as in-stream flows, gravel sedimentation, diversion structures, predation, ocean harvest, etc.
- Because the salmon mortality model operates on a daily time step, a disaggregation procedure is required to use the monthly temperature model output. The salmon model computes daily temperatures by using linear interpolation between the monthly temperatures, which are assumed to occur on the 15th day of the month.
- The application of the IOS model is used to address salmon life cycle stages which are ecological, not evolutionary.
- Salmon models do not address mortality, life cycle, or temperature effects on green sturgeon, or delta smelt.